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Dr. Donald G. Buth
February 23, 1949–May 31, 2022

Donald G. Buth, age 73, of Van Nuys, California passed away on Tuesday, May 31, 2022. Don was born on February 23, 1949 in Chicago, Illinois. He was married to Karen, and had two children, Erik and Jessie.

Academic History—He received a Bachelor's of Science in Zoology from the University of Illinois in 1971, an A.B. in Anthropology from the University of Illinois in 1972, a Master's of Science in Zoology from the University of Illinois in 1974, and a Ph.D. in Ecology, Ethology and Evolution from the University of Illinois in 1978. He did a 2-year postdoc in Biology with Dr. Boyd W. Walker at the University of California (UCLA) from 1978–1980. He was then hired as an Assistant Professor of Biology in 1980 at UCLA in the Department of Biology (later Department of Organismic Biology, Ecology, and Evolution and then Department of Ecology and Evolutionary Biology (EEB)) and promoted to Associate Professor and then Full Professor. He was a Professor at UCLA from 1980–2022.

Teaching—Don taught over 18 courses at UCLA during 1980–2022. Examples include: Ichthyology (EEB 112), Parasitology (EEB 181), Field Biology of Marine Fishes (EEB 164), Systematics & Taxonomy (EEB 202), Principles of Systematic Biology (EEB 130), Population Genetics (Biol 135), Biology of Vertebrates (EEB 111), and Evolution (Biol 120). Don was an exceptional teacher and educator. His teaching style was fantastic; slow

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and steady, clear and accurate, and most of all, fun and engaging. He was always prepared and organized for lecture. He would present a topic that was made clear to the students, engage the students with important scientific content and concepts, then always manage to throw in relevant stories about his own experiences. Students were always laughing during his lectures, but most importantly they were learning! He was extremely passionate about his teaching, and honestly cared about his students. He also included interesting interactive labs, such as dissections as well as many field trips and field experiences. Don took his Ichthyology class on an overnight camping and collecting trip to the tidepools in San Simeon, California for over 30 years. He took the same class to Belmont Shore in Long Beach later in the quarter and did a large beach seine (three pulls of the net during the day and three at night to show different fish assemblages with the changing tide). Both of these field trips were not during the scheduled class time and were usually on the weekend. This shows the kind of commitment Don had to his students. Many professional biologists know what they know about fishes because they took Don Buth's UCLA Ichthyology course (myself included).

Honors—In 2017 he was a recipient of UCLA's highest honor for teaching, the Distinguished Teaching Award, and was honored by the UCLA Academic Senate. He also received the UCLA Departmental of Ecology and Evolutionary Biology Distinguished Teaching Award in 2004, 2008, and 2015 and the UCLA Alumni Eby Award "For the Art of Teaching" in 2017. He received the Meritorious Teaching Award in Ichthyology from the American Society of Ichthyologists and Herpetologists and American Elasmobranch Society (ASIH-AES) in 2016 and he became a Fellow of American Association for the Advancement of Science (AAAS) in 1987. In 2023, the Southern California Society of Parasitologists (SCSP) held a symposium called "Dr. Donald G. Buth Memorial Parasitology Symposium" at the Southern California Academy of Sciences (SCAS) Annual Meeting at UC Santa Barbara honoring his research and legacy.

Students—Don was an advisor to 35 graduate students and postdocs. His passion for inclusion was sincere and he always made his students feel deserving and capable. He advised students on a range of research projects, from population genetics, to taxonomy of fishes, to fish parasitology. He held his students accountable, yet was an extremely dynamic and helpful advisor. He held regular lab meetings that were always productive and fun, and typically included brownies. He stayed in touch with many of his former students and often collaborated on research and teaching.

Research—His own research focused on phylogenetic systematics; systematics and evolution of reptiles and cypriniform, gasterosteiform, and perciform fishes; application of enzymatic methods in systematics; parasitology of marine fishes; and invasive fish species and their role in genetics of ecosystems. He authored over 100 scientific papers; of note, the 1999 paper "The use of isozyme characters in systematic studies" (Biochem. Syst. Ecol. 27:117–129), the 2001 paper "Allozymic and isozymic evidence for polytypy in the North American catostomid genus *Cycleptus*" (Copeia 2001:899–906), and the 2003 paper "Allozymic variation and population structure in the California grunion, *Leuresthes tenuis* (Atheriniformes: Atherinopsidae)" (Copeia 2003:594–600). He co-authored two chapters in the book "Intertidal Fishes: Life in Two Worlds" called "Systematics of intertidal fishes" and "Biogeography of rocky intertidal fishes." He also contributed to the 2nd edition of the book "Miller and Lea's Guide to the Coastal Marine Fishes of California" and helped with writing, revising, and editing many of the dichotomous keys and text of this classic fish identification book. Later in his career he began to emphasize fish parasites in his research. He had a particular

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interest in all things digene, but branched out to marine leeches and parasitic isopods. Don's command of his field of research (ichthyology, parasitology, and systematics) was exceptional. He was considered an authority in his field and thus was a section editor for the Journal of Ichthyology and Herpetology for over 30 years.

Editor—He served as an editor or editorial board member for the ASIH Journal Copeia (now Journal of Ichthyology and Herpetology) from 1982–2022. He was described by his peers as "a thoughtful, passionate and stubborn editor who was dedicated to improving the work of others." Additional services to ASIH include: Genetics, Development and Morphology Editor of Copeia (1985–1993), General Ichthyology Editor of Copeia (2002–2022), Copeia Editorial Board (1982–84, 1993–96, 1999–2001), Board of Governors (1983–98, 2003–2022), Long Range Planning and Policy Committee, Editorial Policy Committee, Nominating Committee, Environmental Quality Committee, and Executive Committee. He was also an editor of the Isozyme Bulletin from 1994–96.

Service—He served on the Board of Directors for SCAS from 1994–1996 and again from 2004–2007. He was the President and founding member of the SCSP from 2016–2018. He was also a founding Fellow of the Willi Hennig Society and was on the Coordinating Board of UC Water Resources Center from 1990–97, the UCMEXUS-CONACYT Grants Advisory Committee in 2000 and was a reviewer of NSF grant proposals and journal articles for: American Midland Naturalist, Animal Conservation, Aquatic Living Resources, Aquatic Sciences, Biochemical Genetics, Biochemical Systematics and Ecology, Biological Conservation, Brimleyana, Bulletin of the Southern California Academy of Sciences, California Fish and Game, Canadian Journal of Zoology, Cladistics, Comparative Biochemistry and Physiology, Copeia, Diversity and Distribution, Environmental Biology of Fishes, Evolution, Herpetologica, Herpetological Journal, Italian Journal of Zoology, Journal of Fish Biology, Journal of Heredity, Journal of Herpetology, Journal of the University of Kuwait (Science), Marine and Freshwater Research, Molecular Ecology, New Zealand Journal of Zoology, Revista de Biologia Tropical, Science, Southwestern Naturalist, Systematic Zoology/Biology, Transactions of the American Fisheries Society, Tulane Studies in Zoology and Botany, Zoological Studies (Academica Sinica Taiwan).

Patronyms—His love and passion for systematics and taxonomy was instilled in his teaching, and as such, he always discussed the importance of the codes of nomenclature or "rulebook" that govern biological taxonomic nomenclature. Due to his mentorship and inspiration to many of his graduate students, Don has three species named in his honor: a marine leech, *Heptacyclus buthi* (Burreson & Kalman, 2006); a parasitic copepod, *Majalincola buthi* Tang & Kalman, 2008; and a guitarfish *Pseudobatos buthi* Rutledge, 2019.

While I was at UCLA as Don's parasitology PhD student, I taught multiple laboratory courses under his supervision. I spent a lot of time with Don in the lab, classroom, and the field. I assisted him in the field at various field research locations, such as the Bodega Marine Lab, San Simeon, and Belmont Shore, Long Beach. I enjoyed every moment listening to him describe how to pull a seine net, how to distinguish various species of tidepool sculpins, and how to deposit museum vouchers. I miss working with him in the field and seeing him arrive in his 1980's Chevy Camaro and him wearing his jean jacket. I miss meeting him in his office to discuss a reorganization of the UCLA museum collection. I miss discussing the latest parasite projects he was planning with his students. I miss just talking about everyday things and laughing at his stories. I miss how proud he was of his long hair.

Not only was I a student of Don's at UCLA, but I am a student of his for life. Every time I spoke with him after I graduated, I still learned something new. I miss him terribly and still find

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myself in my office thinking "I have to ask Buth about that!!!" I feel lucky to have had him as an advisor and mentor during my time at UCLA and will cherish all my memories of him.

I miss you Buth. Although you are gone, you will never be forgotten. I know wherever you are, you are telling stories and making everyone laugh.

Rest in peace Don, the "Pinball Wizard."

—Julianne Kalman Passarelli, PhD

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A Brief Survey of the Fishes, Algae, and Mega-Invertebrates of the Human-made Rincon Island and Nearby Natural Reefs, Southern California

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Abstract.—This study was designed as a brief survey of the marine community at Rincon Island, a human-made island off the coast of California that was constructed in 1957 for oil and gas production and processing. The purpose of the study was to inform the State of California about the ecological conditions at the island for decommissioning planning. The biota at the island had not been comprehensively surveyed since the 1970s. We conducted scuba belt-transect and photoquadrat surveys of the fishes, invertebrates and algal cover at Rincon Island and nearby natural reefs in the fall of 2020. Changes at the island have occurred over time; for example, we found a lack of red urchins, a paucity of sea star diversity, and an invasive bryozoan previously not observed at the island. However, many fauna and flora have persisted as dominant species for five decades. Our findings indicate that the island's complex armor revetment extending from the seafloor to above the splash zone and the varied wave exposure and currents around the installation provide a locally unique ecosystem that is significantly different from the small nearshore rocky reefs scattered in an area of predominately silt and sand. As found in many studies of other kinds of artificial habitats, the island supports a diversity of marine life greater than what would have been found in the area without its presence.

In 1954, the California State Lands Commission (CSLC) contracted the construction of an artificial island in the eastern Santa Barbara Channel designed for the production and processing of oil and gas. Construction of Rincon Island, located about 0.9 km offshore, began in 1957 and ended in 1958 (Fig. 1) (Blume and Keith 1959). The island, connected to the mainland by a concrete-pile supported causeway, was constructed over habitat characterized as mud and sand with sparsely distributed low-lying rock outcrops on the coastal shelf. In 2017, the oil company lessee upon bankruptcy relinquished the holding to the State of California. The quitclaim (transfer) marked the end of operations of the last offshore oil drilling and production facility in State waters (demarcated inshore of 3 miles) in the Santa Barbara Channel. Immediately following, CSLC began the public process of planning the decommissioning and final disposition of Rincon Island.

Although the island was constructed for oil production, it was anticipated that the construction of the armor revetment around the island would "favorably alter the environment

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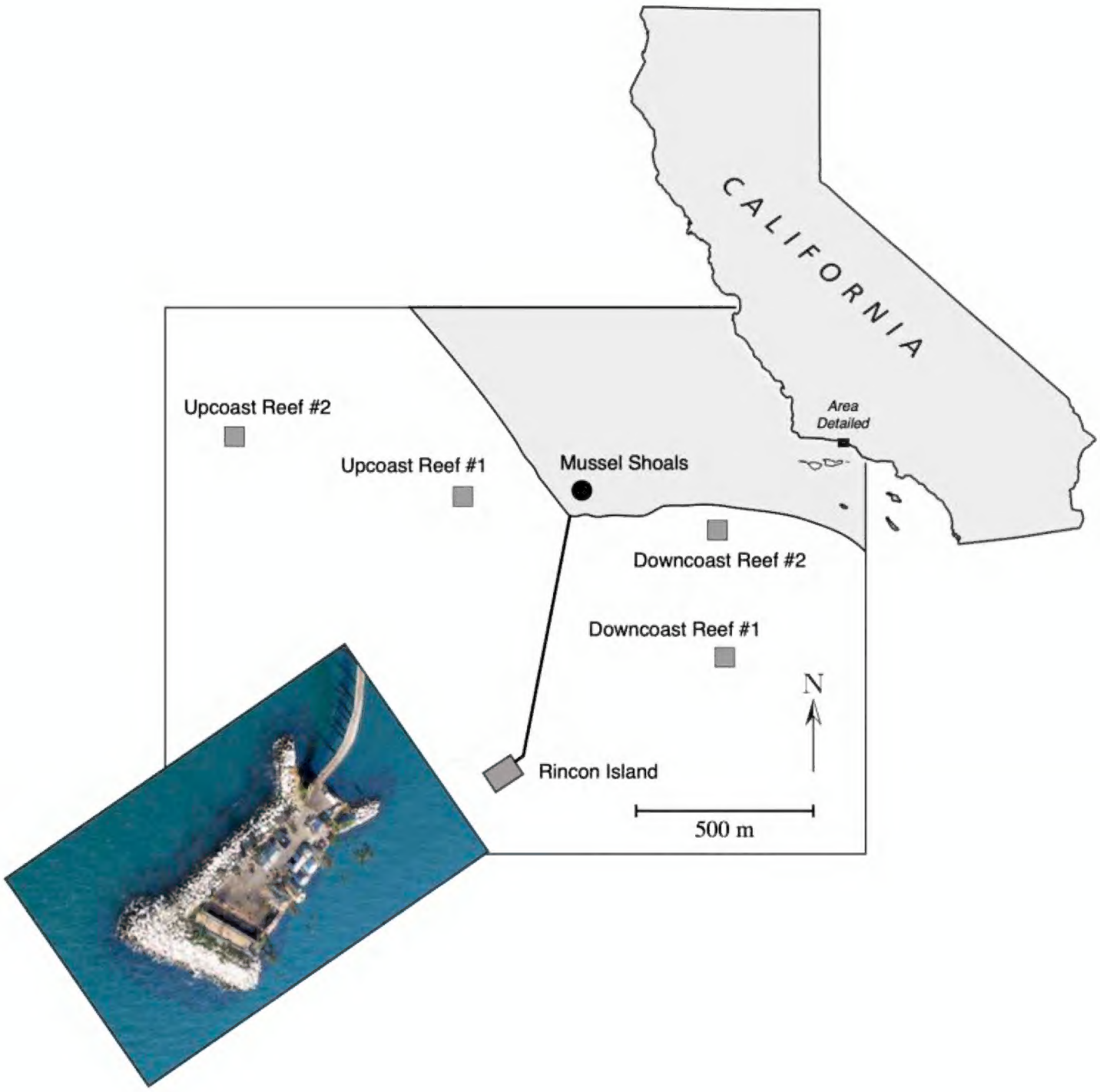

Fig. 1. Location of Rincon Island and the four natural reef study sites.

for marine biota in the area" (Keith and Skjei 1974).[1] The building specifications required that it be solid and composed of natural materials. The perimeter of the island, 1.3 ha at mean lower low water and 2.5 ha on the seafloor, is buttressed with 55,507 m^3 of armor rock extending from above the splash zone to a depth of 11–14 m at the base of the island. Additionally, the western, seaward, exterior is reinforced with a jumble of 1,100 cement tetrapods, each having four 2 m long concrete legs that are greater than 0.6 m in diameter at the end. Comprehensive ecological surveys were conducted in 1958–1960 by Carlisle et al. (1964), 1960s–1970s by Brisby in Keith and Skjei, and 1976–1977 by Johnson and deWit (1978).[2] Carlisle et al. reported that the island served to enhance the sandy seafloor

[1] Keith, J.M., and R.E. Skjei. 1974. Engineering and ecological evaluation of artificial-island design, Rincon Island, Punta Gorda, California. U.S. Army Corps of Engineers, Coast Engineering Research Center Technical Memorandum No. 43.

[2] Johnson, G.F., and L.A. deWit, L.A. 1978. Biological effects of an artificial island, Rincon Island, Punta Gorda, California. U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Miscellaneous Report No. 78-3.

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soon after construction. All studies concluded that the island was a successful example of a human-made reef (HMR) supporting an abundant and diverse community of flora and fauna including species targeted in sport and commercial fisheries (reviewed in Supplement 1). Artificial habitats can have a have a positive effect on species attracted to these kinds of sites. There is a wealth of information demonstrating that artificial habitats can enhance both production and ecosystem services (e.g., Claisse et al. 2014; Granneman and Steele 2014), and this is particularly likely if well designed and in the context of fishery management (reviewed in Pondella et al. 2022).

As the first phase of decommissioning Rincon Island, CSLC, in collaboration with the Department of Conservation's California Geological Energy Management Division, commenced permanent well abandonment operations in July of 2018 that were completed in June 2020. The first step of Phase 2 was the completion of a feasibility study (FS).[3] The information provided in the FS provides information for decommissioning planning, public outreach and development of California Environmental Quality Act (CEQA) documentation. The FS includes a summary of in-depth data gathering, review and analysis of the existing physical facilities and environmental conditions, and an initial environmental assessment to identify potential environmental issues and estimated economic cost associated with three primary disposition alternatives in consideration: island "reuse" that retains the existing facilities with remediation to remove any remaining environmental risks, "reefing" with the removal of the causeway and connecting wharf on the island with remediation, and complete "removal" of the existing island and associated structures.

In this paper, we summarize findings from the biological evaluation we originally reported in the FS to inform the State about the current ecological conditions at Rincon Island. We conducted a brief scuba survey of the fishes, macroinvertebrates and macroalgae at Rincon Island and four nearby rocky reefs in fall 2020 to compare community structure in the artificial and natural habitats. We discuss what can be ascertained of changes in community structure at Rincon Island since its installation and characteristics that indicate the HMR likely is productive habitat.

Materials and Methods

Over the course of four nonconsecutive days, from 9 October to 5 November 2020, scuba divers performed a series of belt transects for fishes, macroinvertebrates, and giant kelp (*Macrocystis pyrifera*) at Rincon Island and at four previously unnamed natural rocky reefs near the island. Two of the natural reefs are located to the northwest (upcoast) and two to the northeast (downcoast) of the island, the closest reef is 0.8 km from the island (Fig. 1). See Supplement 2 for the survey site locations, schedule, number of transect samples, and water depth of the transects conducted at Rincon Island and the four natural reefs.

Two or three scuba divers working together performed surveys at each locality. Each belt transect was 30 m long and 2 m wide (covering an area of 60 m^2). The transect length was delineated by a measuring tape laid along the bottom (Love et al. 2012). The divers conducted four transects along each of the four sides of Rincon Island: two transects were over the armor revetment near the mud seafloor and two transects were shallower on the revetment slope at a depth half that of the deeper transects. The depths at which the island's rocks and tetrapods

[3] California State Lands Commission. 2022. Final Rincon Phase 2 Decommissioning Feasibility Study. https://www.slc.ca.gov/content-types/rincon-phase-2-decommissioning-feasibility-study/.

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meet the sea floor vary depending on side: west side, 14 m; south side, 14 m; north side, 12 m, east side, 11 m. The four natural reefs were patch-like, and the number of transects completed by the divers at each of those sites depended in part on the size and shape of the reef and on water visibility. All fishes and mobile benthic macroinvertebrates encountered by the divers along the belt transects were recorded. Kelp stipes (i.e., frond strands growing from holdfasts) were counted along the belt transect, a common and standard measure that is a predictor of canopy biomass (McPherson and Kudela 2022). Other algae were documented through photoquadrats (see below). One diver identified, counted, and estimated the total length of all fishes that occurred within 2 m of the bottom substrate. A second diver identified and counted all of the macroinvertebrates observed. All animals were identified down to lowest possible taxon. Based on the counts, abundances were estimated as densities, the number of individuals per 100 m^2 for fishes and the number of individuals per 1 m^2 for invertebrates. Habitat complexity was characterized by substrate rugosity at the locations of six photoquadrats along the transect. Rugosity was visually estimated as the change in the height of the rocky substrate classified as 0–0.1 m, 0.1–1 m, 1–2 m, or greater than 2 m, and later coded for analysis as 1, 2, 3, and 4, respectively.

Photographic surveys were conducted to assess the algae and sessile benthic macroinvertebrates at Rincon Island and the natural reefs. Images were taken at six randomly spaced sample markers along the 30 m transect tape. The diver would photograph each sample area under a marker on the tape by holding the staff of a T-shaped guide against the substrate, and capturing the length of the measurement reference bar marked in 10 cm increments within the field of view fixed by the length of the staff (Fig. 2A). Initially, when sampling the north and west side of Rincon Island, the images were set by the T-bar at a distance from the substrate that encompassed a 1 m x 1 m quadrat area; however, visual resolution of the imagery was impaired by turbidity at the base of the revetment. Subsequently, the T-bar was modified to reduce the field of view to fit a 0.5 m x 0.5 m quadrat (0.25 m^2 area) and improve resolution. The east and south sides of Rincon Island were surveyed using this smaller field of view. Regardless of the size of the field of view, the quadrat area analyzed in the images was 0.25 m^2.

In the laboratory, the photoquadrat images were uploaded into *CoralNet*, an open-source online system for benthic resource analysis (https://coralnet.ucsd.edu/source/2294/). We used the Uniform Point Contact (UPC) analysis tool to quantify the sessile macroinvertebrates and algae in the images. *CoralNet* permits the user to define the size of the UPC grid and the number of points in the grid to annotate on an image. We chose to overlay 25 points equally spaced in a 5x5 grid configuration over an approximate area of 0.25 m^2 on each image (Fig. 2A). The quadrat area was sized to the image using the measurement reference bar that was included in the photograph. This allowed us to include data from images with the larger field of view of the 1 m T-bar as is shown in Fig. 2A. Each annotation entered in the *CoralNet* system by the user specifies what was seen on the image under a point: an organism identified to the lowest taxonomic level possible; type of hard or soft substrate; or unresolvable (either water or unidentifiable under the point). Images with more than five unresolvable points were excluded from the dataset, so the total number of points per quadrat ranged from 20 to 25 points. Two of 150 images were excluded. The analysis was performed on 148 images; 28 of the 148 images had 1-5 unusable data points. If the UPC point overlayed the T-bar, then what was adjacent and likely to be under the marker was annotated. The abundance of each identifier (an organism or substrate type) under one or more UPC grid points was measured as the proportion (percentage) of 25 points. This is a relative measure rather than an estimate of areal coverage in an image. Relative abundance of an organism was examined as three measures: the points within a

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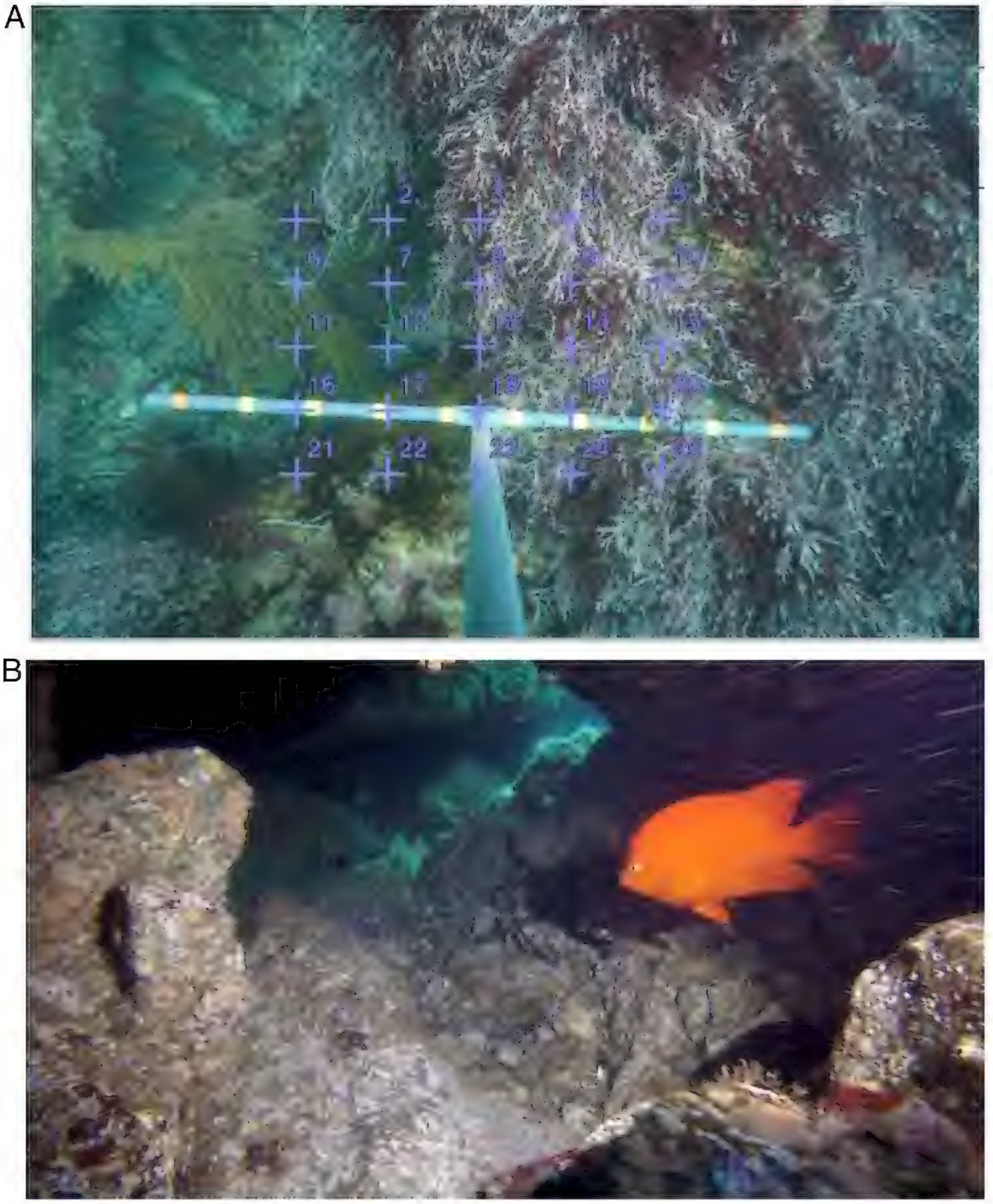

Fig. 2. (A) Example of a photoquadrat image from Rincon Island viewed in *CoralNet* with the 5 x 5 uniform point contact (UPC) grid overlay; (B) Typical view from inside a cave formed by the tetrapods that armor parts of Rincon Island. A garibaldi (*Hypsypops rubicundus*) is shown.

quadrat, the points summed across all quadrats, and frequency of occurrence (FO) in the total number of quadrats. We defined categories of relative abundance: 0, absent; 1–10% of points or FO, uncommon; 10 to 50% of points or FO, common; 51 to 100% of points or FO, abundant. In addition to the UPC method to estimate relative abundance, a second method (non-UPC) was used to estimate the density (number per 1 m^2) of gorgonians (soft corals) in the images. In the

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non-UPC method, all gorgonians that occurred, fully or partly, within the 0.25 m^2 quadrat area were identified to species, if possible, counted and measured.

Statistical analyses were performed on the measures of abundance of the most common fishes and mobile invertebrates to determine if there were differences between Rincon Island (RI) and the combined reef sites. We used the nonparametric 2-group Wilcoxon test to test the null hypothesis of no group difference, $\alpha = 0.05$ (JMP 15 Pro, 2021) given the unequal group variances of the transformed data. We used Primer v6 (Clarke and Gorley 2006) to examine the species assemblage data in relation to the islands and combined reefs. The fishes, sessile invertebrates, and mobile invertebrates were analyzed separately. First, the count per sample (transect or quadrat) of species and types identified to a higher taxonomic level were square-root transformed to reduce the effect of large outliers. Next, Bray-Curtis similarity coefficients were calculated to quantify the resemblance between samples, and a similarity matrix was generated. Then, natural groupings of samples were examined using hierarchical clustering with the group average linkage option and multidimensional scaling (MDS) ordination. The primary hypothesis to be tested was whether or not there is difference among the assemblages found at Rincon Island and nearby natural rocky reefs combined. The Analysis of Similarity (ANOSIM) sample test statistic, R, ranges from 0 (no difference between groups) to 1 (all dissimilarities between the groups are larger than any dissimilarities among samples within either group). A statistically significant ($p < 0.05$) but negligibly small R value close to 0 indicates that species composition strongly overlaps and the difference between groups may not be biologically meaningful.

Results

A total of 16 transects were conducted at the island and 16 at the natural reefs to survey fishes. Photoquadrat surveys were conducted at only 2 of the 4 reefs, the shallow downcoast reef #1 and deep upcoast reef #2. These and the surveys of mobile invertebrates, substrate rugosity, and kelp stipes at Rincon Island and the reefs were less extensive than the fish surveys due to diving conditions and logistical limitations when two rather than three divers were performing the surveys. Turbidity from suspended particulates during the surveys was highly variable both from survey to survey and with depth and location around the island and at the natural reefs. An effort was made to also survey the natural soft-bottom habitat away from the influence of the island, but we were unable to conduct the survey due to very poor visibility.

Surface water temperatures in the offshore area typically range from 12.8 to 19.4 °C, mean 16.7 °C (CSLC 2022). At Rincon Island, the surveyed bottom temperature was 20.0 °C at the shallow transect depth (5-7 m), and 18.9-20.0 °C at the deep transect depth (11-12 m); at the reefs, the bottom temperature ranged from 17.2-18.9 °C (Supplement 2). The mean high water elevation at Rincon Island[4] is 1.34 m with a mixed semi-diurnal tidal range[5] of 1.64 m.

The physical structure supporting the biological communities at Rincon Island and the natural reefs are quite different. The sloped armor revetment surrounding the island is composed of rock boulders that create crevices of a variety of sizes. In addition, the west side of the island is reinforced with concrete tetrapods creating caves in excess of 3 m deep at the

[4] Hapke, C.J., D. Reid, B.M. Richmond, P. Ruggiero, and J. List. 2006. National assessment of shoreline change: Part 3: Historical shoreline changes and associated coastal land loss along the sandy shorelines of the California coast: U.S. Geological Survey Open-file Report 2006-1219.

[5] Santa Barbara, CA - Station ID: 9411340, https://tidesandcurrents.noaa.gov/.

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Table 1. Abundance of flora at Rincon Island and two natural reefs.

	Rincon Island			Natural Reefs		
Algae	Abundance	Proportion of images	Proportion of UPC points	Abundance	Proportion of images	Proportion of UPC points
Red seaweeds[1]	Common	73%	28.10%	Common	70%	22.90%
Brown seaweeds[2]	Common	30%	4.70%	Uncommon	2%	0.10%
Coralline algae, Articulated[3]	Common	13%	2.40%	Not obs.	0%	0.00%
Feather boa kelp[4]	Uncommon	4%	0.70%	Not obs.	0%	0.00%
Coralline algae, Crustose[5]	Uncommon	2%	0.20%	Uncommon	9%	0.40%
Giant kelp[6]	Uncommon	1%	0.30%	Common	39%	6.10%
Unidentified flora		5%	0.50%		0%	0.00%

[1] Class Florideophyceae.
[2] Class Phaeophyceae.
[3] Possibly *Bossiella* spp. and/or *Calliarthron* spp.
[4] *Egregia menziesii*.
[5] Possibly *Lithothamnion* spp., *Lithophyllum* spp., and/or *Pseudolithophyllum* spp.
[6] *Macrocystis pyrifera*.

seafloor and cavernous gaps in all directions up the slope of the seawall (Fig. 2B). In contrast, the natural reefs in this study were mostly of very low relief bedrock, rarely exceeding 1 m in height. More often they were relatively flat rock with few crevices. Rugosity measured by the divers at Rincon Island ranged from an index of 1 (0.1 m or less) to 4 (>2 m), mean 3.0, SD 0.9 (index 3 is 1–2 m). In contrast, natural reef habitat was significantly less rugose ranging from 1 to 3, never exceeding 2 m (mean 1.9, SD 0.5; index 2 is 0.1–1 m) at two reefs combined ($\chi^2 = 33.96$, $df = 1$, $p < 0.0001$).

Much of the habitat at both Rincon Island and the natural reefs was covered with a carpet of fuzzy, light brown "turf" primarily composed of colonial hydroids, bryozoans, and tunicates, bits of detritus, and biofilm. In the UPC analysis, turf occupied 38% of the points in all the photoquadrats from Rincon Island and 41% of the UPC points in photoquadrats from the shallow downcoast reef #1 at 7 m depth and deep upcoast reef #2 at about 12.5 m depth combined. Divers observed mussel shell debris on the lower reaches of the island rock revetment that had broken off at shallow depths not surveyed. Shell debris from mussel and other mollusks was common, occurring in 11% of the photoquadrats and occupying 3% of the UPC points at Rincon Island. For comparison, shell debris was observed in 6% of the photoquadrats and 1% of the UPC points at the natural reefs.

A minimum of six types of algae were identified in the UPC analysis from both Rincon Island and the natural reefs (Table 1). Although we attempted to identify feather boa kelp (*Egregia menziesii*) and giant kelp (*Macrocystis pyrifera*) to species, small plants of these species were not distinguishable from other brown algae. There were both similarities and differences in the algal assemblages at Rincon Island and natural reef habitats.

At Rincon Island, giant kelp was patchy and sparse. Only a small patch was seen from the boat deck on the east side of the island. In the kelp stipe count survey, more kelp occurred at the shallower downcoast reef #2 than at Rincon Island: 870 stipes/transect (SE = 121) and 9 stipes/transect (SE = 5), respectively. However, only three stipes of kelp were seen on transects at the deep upcoast reef #2. Similarly, in the photoquadrat survey, giant kelp was uncommon at Rincon Island occurring in only 1% of the photoquadrats and 0.3% of the UPC points.

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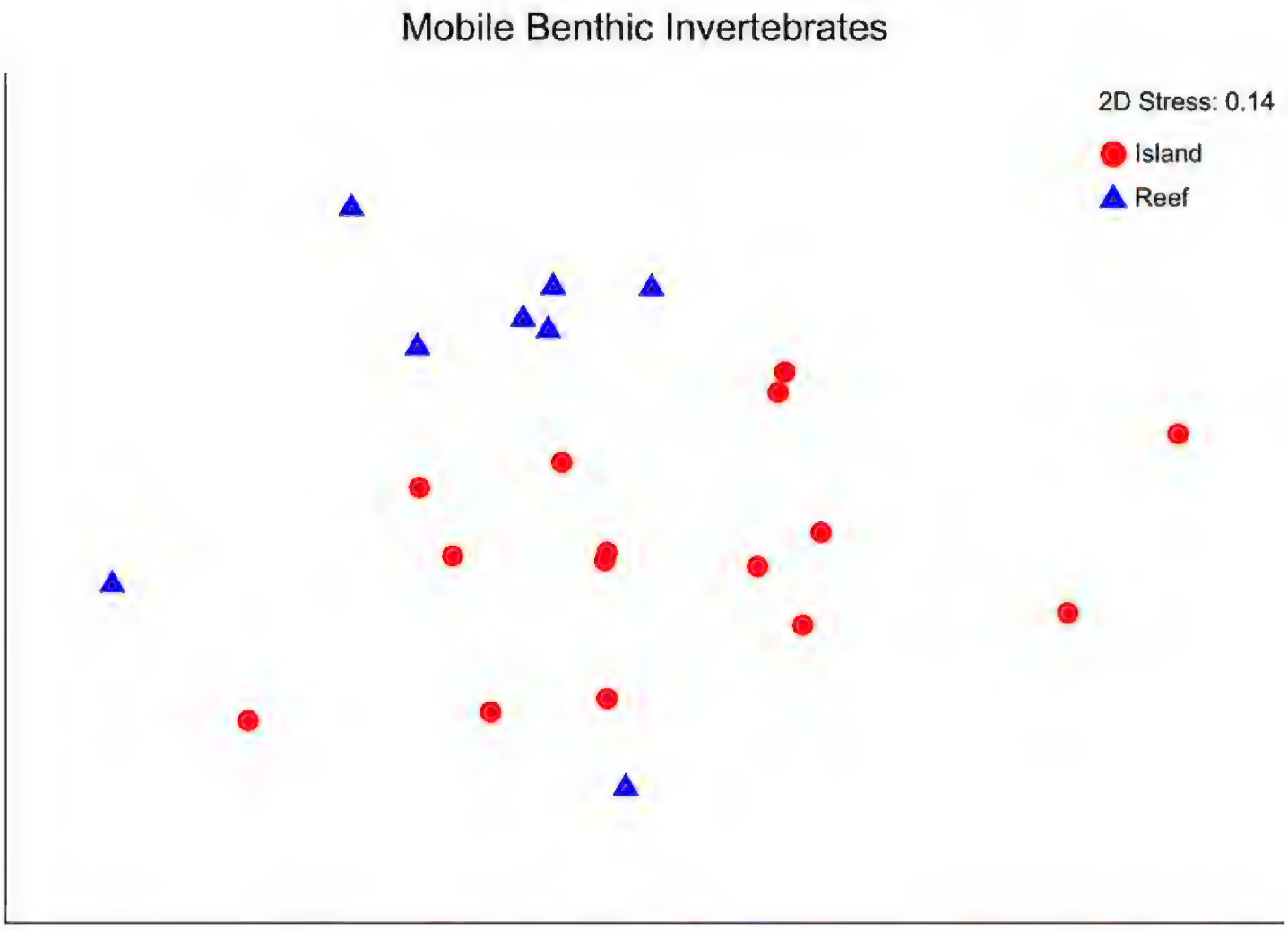

Fig. 3. Non-parametric multidimensional scaling plot of the assemblages of mobile invertebrates observed around Rincon Island and the surveyed natural reefs combined: upcoast reef #1, upcoast reef #2, downcoast reef #2.

Giant kelp occurred in 58% of the photoquadrats and under 9.1% of the UPC points at the shallow natural site, downcoast reef #1, where stipes were not counted. As expected from the stipe count survey, kelp did not occur in the UPC analysis of photoquadrats from the deep upcoast reef #2.

Red algae were the abundant and dominant taxa, present in 73% of the images from Rincon Island and 70% of the images from the natural reefs. Red algae occupied 28% of the total of 2350 UPC points in Rincon Island photoquadrats and 23% of 1350 points in reef photoquadrats (Table 1). At the shallower reefs where giant kelp shaded the seafloor, other algae were relatively uncommon. In contrast, brown algae and articulated coralline algae (possibly *Bossiella* spp. and/or *Calliarthron* spp.) ranked second and third in abundance at Rincon Island where giant kelp was uncommon.

A minimum of 19 invertebrate taxa were identified (Supplement 3). Nine mobile species were identified in the transect surveys and a minimum of 10 sessile taxa were observed in the quadrat surveys. No species listed by the Endangered Species Act or species of concern were observed.

The mobile benthic invertebrate species assemblage differed between Rincon Island and the natural reefs combined ($R = 0.28$, $p = 0.01$) (Fig. 3). Two non-fisheries species contributed to the differences in the assemblages at the two habitats; bat stars (*Patiria miniata*) and giant keyhole limpets (*Megathura crenulata*) were more abundant among the suite of species at the natural reefs combined compared to the island ($\chi^2 = 7.06$, $df = 1$, $p = 0.01$; $\chi^2 = 11.77$, $df = 1$, $p < 0.01$; respectively) (Fig. 4). Mean density of the other species did not significantly differ between the two habitats.

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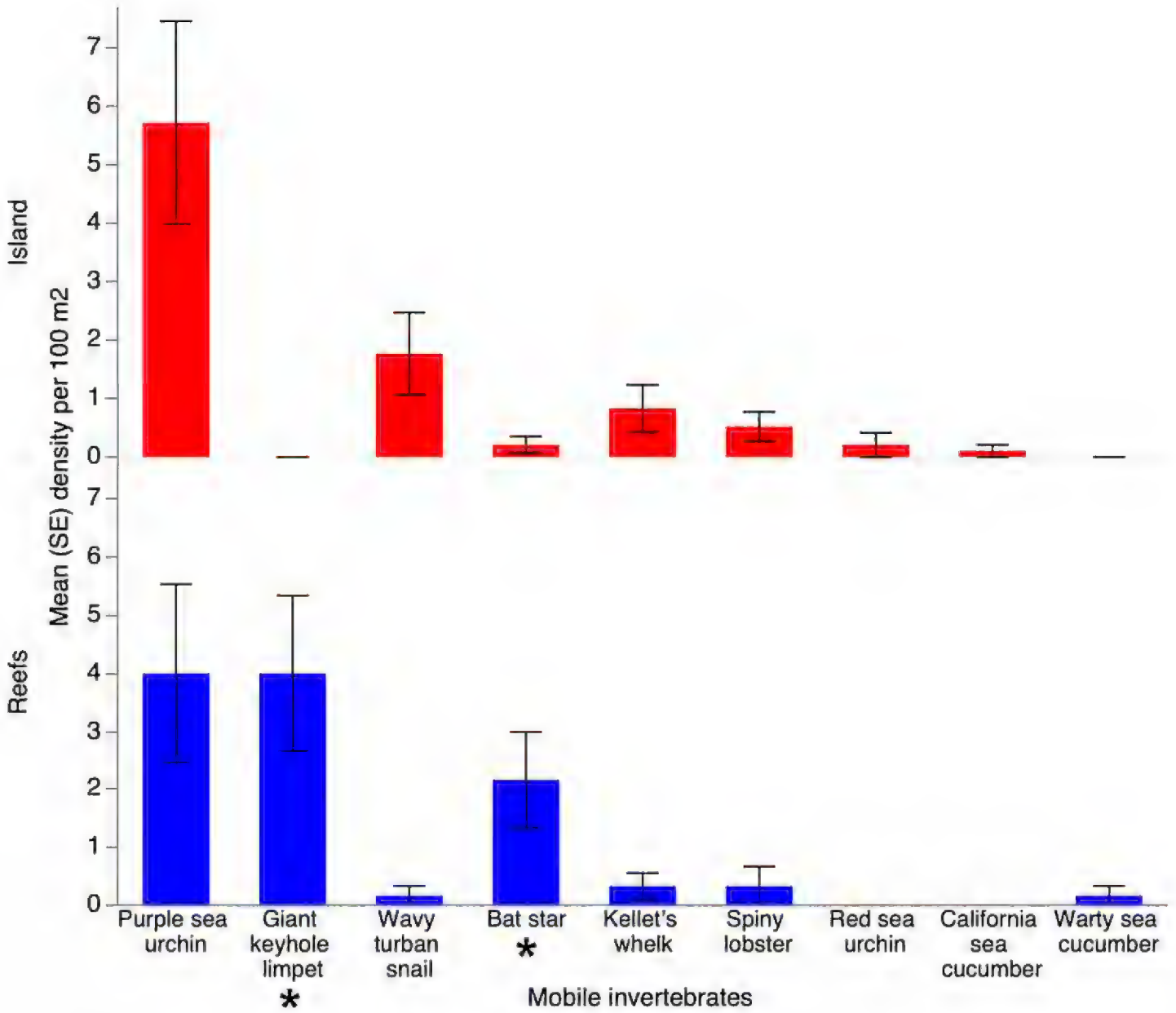

Fig. 4. Density of the mobile benthic invertebrate species observed along belt transects at Rincon Island (top) and three natural reefs combined (bottom). $*p < 0.05$.

Purple urchins (*Strongylocentrotus purpuratus*) dominated the mobile invertebrate assemblage at Rincon Island (Table 2). It occurred in 81% of the transects and was three times more abundant by count than the wavy turban snail, the second most common species occurring in 44% of the transects. In contrast, purple urchins did not dominate the assemblage at the natural reefs combined and was no more common than bat stars and giant keyhole limpets; each of the three species occurred in 60% of the transects with bat stars less abundant by count than the other two species.

Additionally, two commercial fisheries species, spiny lobster (*Panulirus interruptus*) and Kellet's whelk (*Kelletia kelletii*), and the wavy turban snail (*Megastraea undosa*), were common, based on the proportion of transects in which a species occurred, at Rincon Island; the three species were encountered by divers in 25%, 25%, and 44% of the 16 transects, respectively (Table 2). By comparison, spiny lobster and Kellet's whelk, and the wavy turban snail occurred in 10%, 20%, 10% of the 10 transects, respectively, at three natural reefs: upcoast reef #1 (middle depths), upcoast reef #2 (deep), downcoast reef #2 (middle). The fourth reef (shallow) was not surveyed for mobile invertebrates.

The species assemblage of sessile invertebrates at Rincon Island and the rocky reefs combined significantly differed ($R = 0.05$, $p = 0.01$) based on the UPC counts of invertebrate taxa in the photoquadrats (Fig. 5). The dominant taxa at Rincon Island, based on frequency of occurrence in photoquadrats and the number of UPC points occupied in photoquadrats, were

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Table 2. Abundance of mobile invertebrates at Rincon Island and natural reefs.

		Rincon Island (n = 16)				Natural Reefs (n = 10)			
Mobile invertebrates	Scientific name	Abundance	Count	Occurrence in transects	Proportion of transects	Abundance	Count	Occurrence in transects	Proportion of transects
Purple sea urchin	*Strongylocentrotus purpuratus*	A	55	13	81%	A	24	6	60%
Wavy turban snail	*Megastraea undosa*	C	17	7	44%	U	1	1	10%
Kellet's whelk	*Kelletia kelletii*	C	8	4	25%	C	2	2	20%
Spiny lobster	*Panulirus interruptus*	C	5	4	25%	U	2	1	10%
Bat star	*Patiria miniata*	C	2	2	13%	A	13	6	60%
California sea cucumber	*Apostichopus californicus*	U	1	1	6%	N	0	0	0%
Red sea urchin	*Mesocentrotus franciscanus*	U	2	1	6%	N	0	0	0%
Giant keyhole limpet	*Megathura crenulata*	N	0	0	0%	A	24	6	60%
Warty sea cucumber	*Apostichopus parvimensis*	N	0	0	0%	U	1	1	10%

Note: Abundance of mobile benthic invertebrates is based on the proportion of transects where a species occurred at Rincon Island (n = 16 transects) and three natural reefs combined (n = 10 transects). Categories of abundance: Not observed (N), 0; uncommon (U), 1–10%, common (C), 11–50%, abundant (A), 51–100%.

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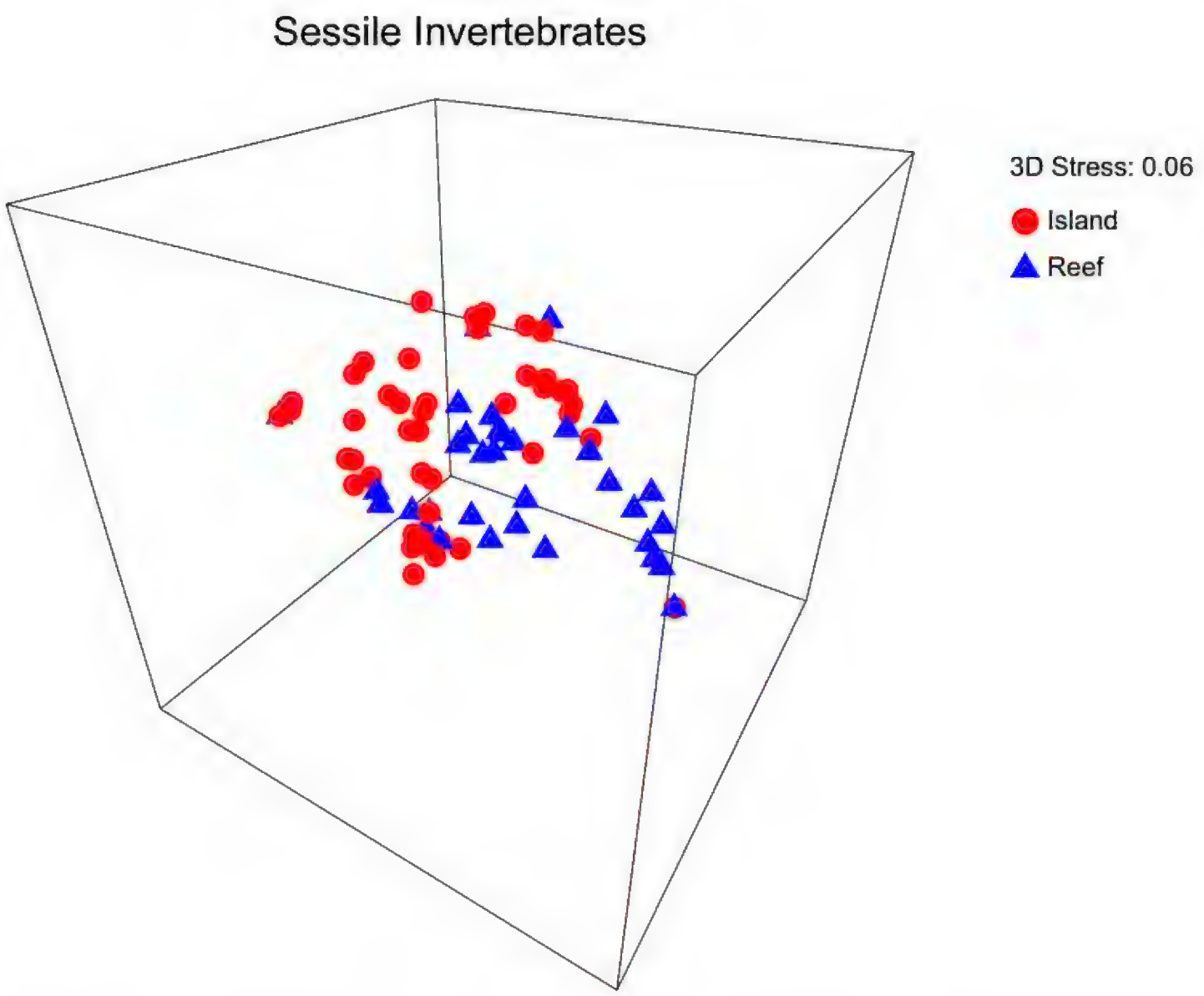

Fig. 5. Non-parametric multidimensional scaling plot of the sessile invertebrates observed around Rincon Island and the surveyed natural reefs combined: downcoast reef #1, upcoast reef #2.

unidentified sponges, California golden gorgonian (*Muricea californica*), brown gorgonian (*Muricea fruticose*), unidentified gorgonians, and southern staghorn bryozoan (*Diaperoforma californica*) (Table 3). The unidentified gorgonians are likely California golden gorgonian or brown gorgonian that are difficult to identify with certainty when polyps were retracted or when resolving the image was difficult.

Several sessile invertebrate species were significantly more abundant in reef habitat than at Rincon Island (Fig. 6). The density of California golden gorgonian was significantly greater at the reefs combined than at Rincon Island ($\chi^2 = 4.19$, $df = 1$, $p = 0.04$) based on the counts of gorgonians in the non-UPC analysis (Table 4). The UPC counts per quadrat for rust-red bryozoan (*Watersipora subatra*) ($\chi^2 = 15.33$, $df = 1$, $p < 0.0001$), southern staghorn bryozoan ($\chi^2 = 4.51$, $df = 1$, $p = 0.034$), and parchment tube worm (*Chaetopterus* sp.) ($\chi^2 = 14.61$, $df = 1$, $p < 0.0001$) were significantly greater at reef habitat than at Rincon Island. The invasive red-rust bryozoan can outcompete native benthic sessile invertebrates for space on rocky reefs. It was detected in 19% of the UPC photoquadrats from the natural reefs and in only 1% of photoquadrats from Rincon Island.

Purple gorgonian (*Eugorgia rubens*), orange cup coral (*Balanophyllia elegans*), and scaled wormsnail (*Thylacodes squamigerus*) were only detected in the UPC analysis of the island photoquadrats and not in the natural reef photoquadrats. Density of purple gorgonian was significantly greater at Rincon Island than at the reefs combined ($\chi^2 = 4.19$, $df = 1$, $p = 0.04$) based on the counts of gorgonians

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Table 3. Abundance of sessile invertebrates at Rincon Island and natural reefs.

		Rincon Island			Natural Reefs		
Common name	Scientific name	Abundance	Proportion of images	Proportion of UPC points	Abundance	Proportion of images	Proportion of UPC points
Unidentified sponges	Porifera	Common	15%	1.10%	Uncommon	9%	0.40%
Southern staghorn bryozoan	*Diaperoforma californica*	Common	14%	1.10%	Common	28%	2.90%
California golden gorgonian	*Muricea californica*	Common	13%	1.50%	Common	26%	2.60%
Unidentified gorgonians	*Muricea spp.*	Common	13%	1.20%	Common	22%	2.60%
Brown gorgonians	*Muricea fruticosa*	Uncommon	9%	0.70%	Common	15%	1.00%
Red gorgonian	*Leptogorgia chilensis*	Uncommon	4%	0.30%	Uncommon	6%	1.00%
Scaled wormsnail	*Thylacodes squamigerus*	Uncommon	3%	0.10%	Not obs.	0	0
Orange cup coral	*Balanophyllia elegans*	Uncommon	2%	0.20%	Not obs.	0	0
Purple gorgonian	*Eugorgia rubens*	Uncommon	2%	0.30%	Not obs.	0	0
Red-rust bryozoan	*Watersipora sp.*	Uncommon	1%	0.00%	Common	19%	3.00%
Parchment tube worm	*Chaetopterus* sp.	Not obs.	0%	0.00%	Common	15%	1.80%

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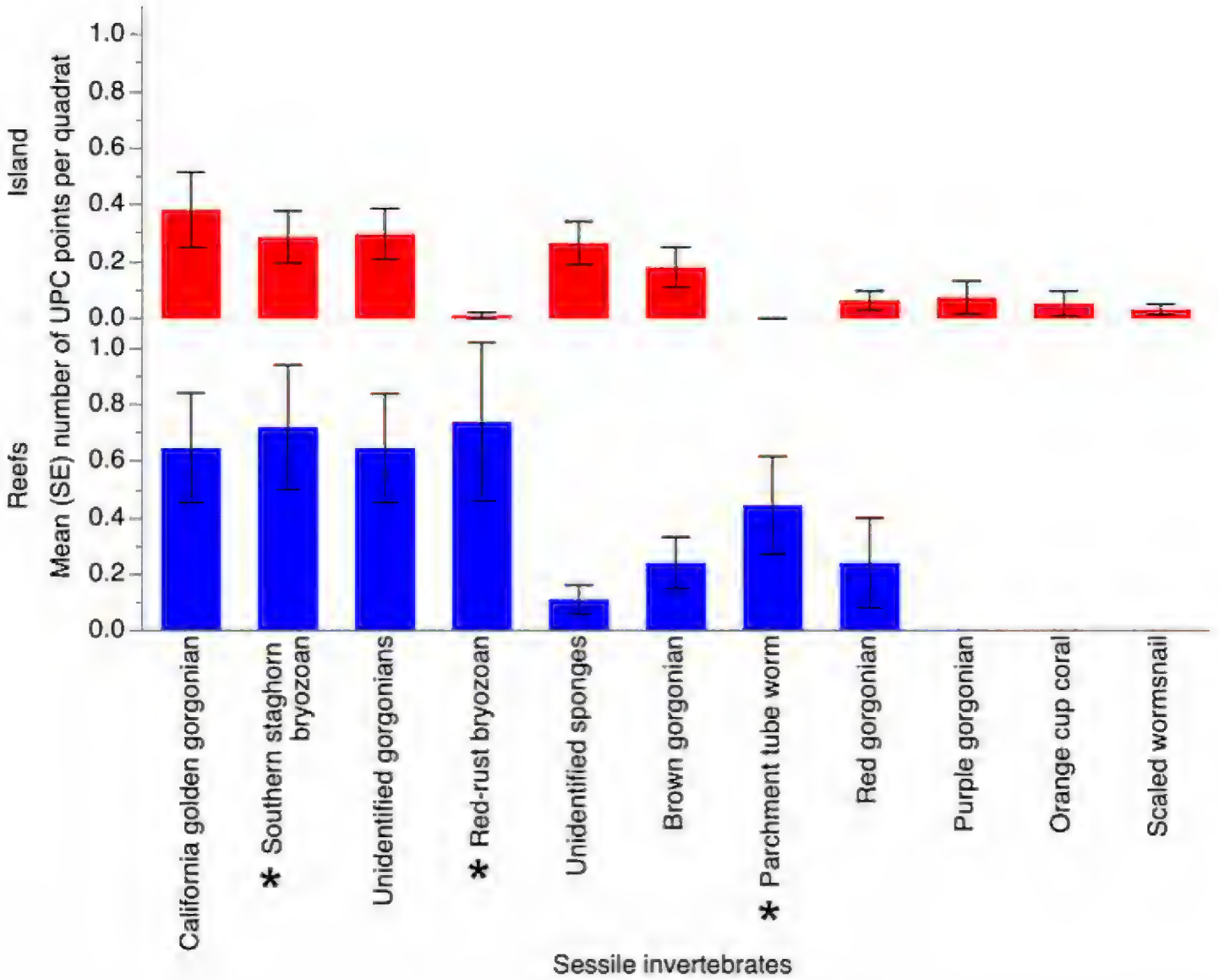

Fig. 6. Mean UPC points occupied by sessile invertebrate taxa per photoquadrats from Rincon Island (top) and two natural reefs combined (bottom). $*p < 0.05$.

in the non-UPC analysis (Table 4) Sponges were more common at Rincon Island than at the reefs although the difference between habitats was not statistically significant (Table 3, Fig. 6).

A total of 1500 fishes, of 28 species, were observed in 32 total survey transects conducted at Rincon Island (16 transects), and four nearshore natural reefs in the vicinity (16 transects) (Table 5). Species richness was greater at Rincon Island than at the four reefs combined. Overall, there were 26 species of fishes seen at Rincon Island and 15 species at the natural reefs. Five species were significantly more abundant at Rincon Island than in reef habitat:

Table 4. Density of soft corals (gorgonians) (number per 1 m^2) at Rincon Island and natural reefs.

		Island			Reefs		
Common name	Scientific name	Total Count	Mean Density	Standard Error	Total Count	Mean Density	Standard Error
Purple gorgonian	*Eugorgia rubens*	43	1.8	0.3	0		
Red gorgonian	*Leptogorgia chilensis*	6	0.3	0	5	0.4	0.1
California golden gorgonian	*Muricea californica*	34	1.4	0.1	51	3.8	0.3
Brown gorgonian	*Muricea fruticosa*	14	0.6	0.1	15	1.1	0.1
Unident. gorgonian	*Muricea* spp.	33	1.4	0.1	44	3.3	0.2
All gorgonians		130	5.5	0.4	115	8.5	0.5

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Table 5. Total number and densities (fish per 100 m^2), including standard errors (s.e.), of all fishes observed at Rincon Island and natural reefs (all sites combined), scaled by the highest to lowest numbers of the island taxa.

		Island			Reefs		
Common Name	Scientific Name	Number	Density	s.e.	Number	Density	s.e.
Topsmelt	*Atherinopsis affinis*	310	32.3	31.2	0	0	0
Blacksmith	*Chromis punctipinnis*	290	30.2	8.7	54	5.6	3.2
Señorita	*Oxylulis californica*	186	19.4	5	52	5.4	3.1
Kelp bass	*Paralabrax clathratus*	72	7.5	0.7	85	8.9	2.4
Sargo	*Anisotremus davidsonii*	53	5.5	3.1	0	0	0
California sheephead	*Bodianus pulcher*	45	4.7	2	21	2.2	0.9
Opaleye	*Girella nigricans*	44	4.6	1.3	42	4.4	2.3
Black perch	*Embiotoca jacksoni*	33	3.4	0.7	14	1.5	0.5
Garibaldi	*Hypsypops rubicundus*	32	3.3	0.8	44	4.6	1.7
White seaperch	*Phanerodon furcatus*	14	1.5	1.2	0	0	0
Brown rockfish	*Sebastes auriculatus*	9	0.9	0.5	7	0.7	0.4
Painted greenling	*Oxylebius pictus*	9	0.9	0.9	1	0.1	0.1
Barred sand bass	*Paralabrax nebulifer*	6	0.6	0.3	26	2.7	0.6
Rock wrasse	*Halichoeres semicinctus*	5	0.5	0.2	0	0	0
Halfmoon	*Medialuna californiensis*	3	0.3	0.2	25	2.6	1.8
Olive rockfish	*Sebastes serranoides*	3	0.3	0.2	0	0	0
Black-and-yellow rockfish	*Sebastes chrysomelas*	1	0.1	0.1	0	0	0
California scorpionfish	*Scorpaena guttata*	1	0.1	0.1	1	0.1	0.1
Giant kelpfish	*Heterostichus rostratus*	1	0.1	0.1	0	0	0
Horn shark	*Heterodontus francisci*	1	0.1	0.1	0	0	0
Island kelpfish	*Alloclinus holderi*	1	0.1	0.1	0	0	0
Kelp rockfish	*Sebastes atrovirens*	1	0.1	0.1	1	0.1	0.1
Pile perch	*Phanerodon vacca*	1	0.1	0.1	0	0	0
Rainbow seaperch	*Embiotoca caryi*	1	0.1	0.1	2	0.2	0.1
Rubberlip seaperch	*Rhocochilus toxotes*	1	0.1	0.1	0	0	0
White seabass	*Atractoscion nobilis*	1	0.1	0.1	0	0	0
Swell shark	*Cephaloscyllium ventriosum*	0	0	0	1	0.1	0.1
Total		**1124**	**116.9**		**376**	**39.2**	

blacksmith (*Chromis punctipinnis)* ($\chi^2 = 12.15$, $df = 1$, $p = 0.001$), señorita (*Oxyjulis californicus*) ($\chi^2 = 11.1524$, $df = 1$, $p = 0.001$), sargo (*Anisotremus davidsonii*) ($\chi^2 = 7.06$, $df = 1$, $p = 0.01$), black perch (*Embiotoca jacksoni*) ($\chi^2 = 5.12$, $df = 1$, $p = 0.024$), rock wrasse (*Halichoeres semicinctus*) ($\chi^2 = 5.74$, $df = 1$, $p = 0.02$) (Fig. 7). Barred sand bass (*Paralabrax nebulifer*) was the only species significantly more abundant in natural reef habitat than at Rincon Island ($\chi^2 = 7.97$, $df = 1$, $p = 0.005$). The densities of 10 species that were observed at both Rincon Island and natural reefs did not differ between habitats (Table 5). There was a significant difference in the assemblage of fishes at Rincon Island (n = 16 transects) and the rocky reefs ($R = 0.356$, $p = 0.001$) (Fig. 8).

Blacksmith was the most numerous fish species comprising 23% of fishes observed. Topsmelt (*Atherinops affinis*) was the second most abundant species numbering 310 fish, however this was based on a school of 300, and a smaller group of 10, that were observed during the survey of the east side of Rincon Island at the shallow depth of 15 ft. Señorita (15.9%) were the third most abundant species, and kelp bass (*Paralabrax clathratus*), the fourth most abundant species, comprised 11% of the fishes observed. Rockfishes as a group (genus *Sebastes*) ranked 12th (1%); brown rockfish (*S. auriculatus*) was the most common rockfish

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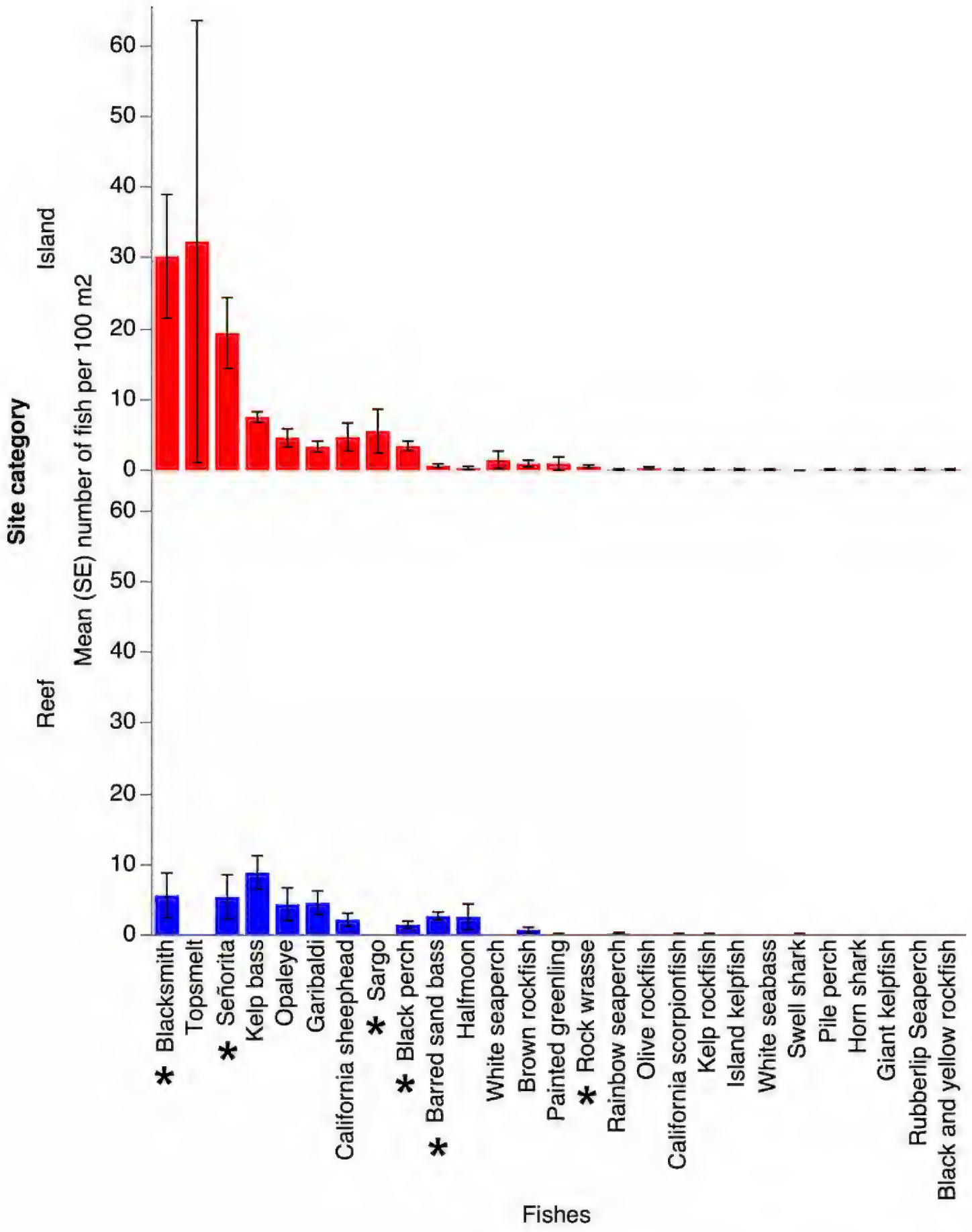

Fig. 7. Average densities (number of fish per 100 m^2) of all fish species observed at Rincon Island (top) and four reefs combined (bottom). $*p < 0.05$.

species, followed by olive rockfish (*S. serranoides*), kelp rockfish (*S. atrovirens*), and black-and-yellow rockfish (*S. chrysomelas*).

Fishes were more abundant at Rincon Island than at the surveyed natural reefs. The average density, excluding topsmelt was 85 fish/100 m^2 (S.E. 14 fish/100 m^2) at Rincon Island and 39 fish/100 m^2 (S.E. 9 fish/100 m^2) at natural reefs combined (Fig. 9). The difference in densities between Rincon Island and the natural reefs combined was statistically significant

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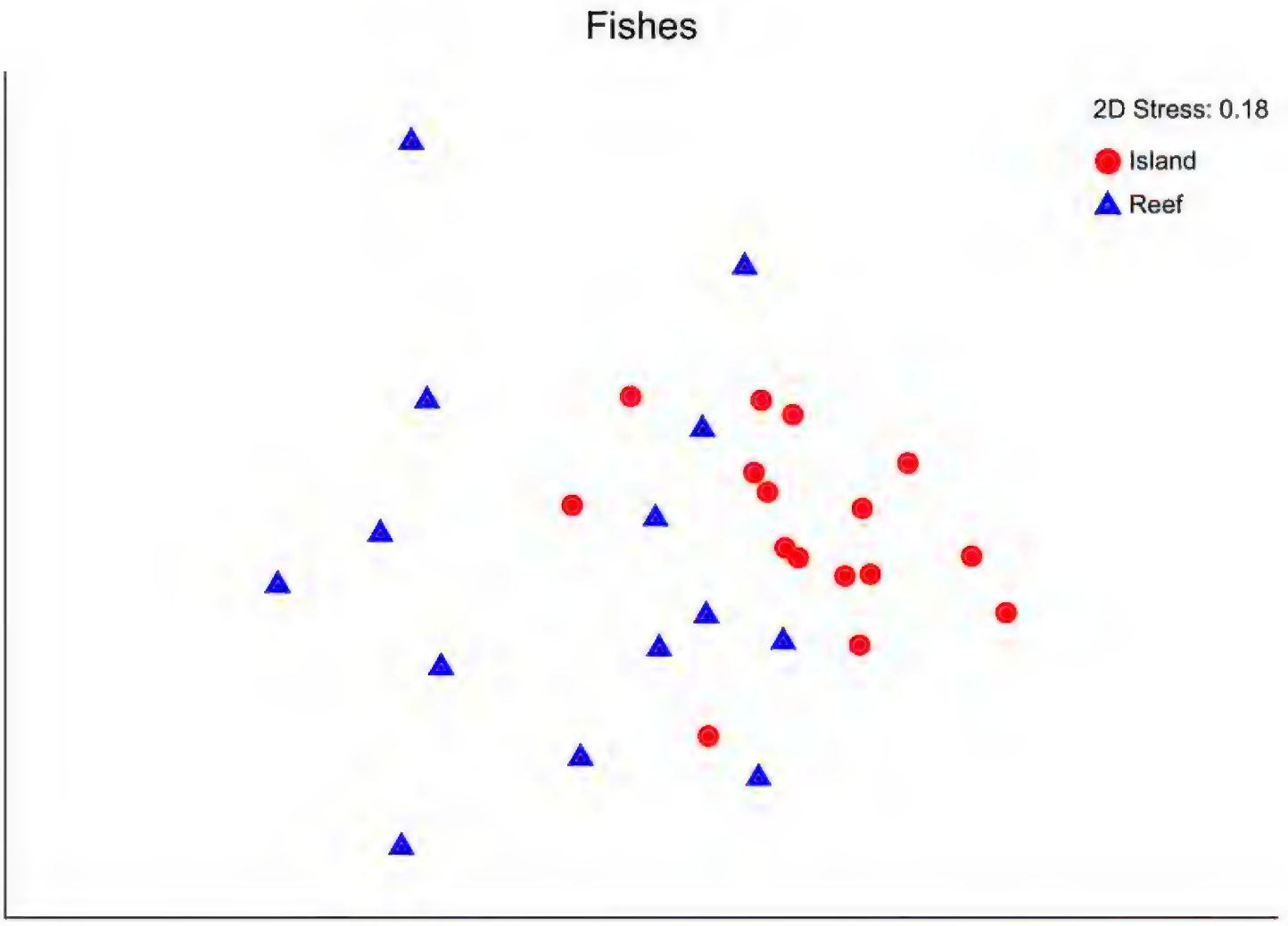

Fig. 8. Non-parametric multidimensional scaling plot of the assemblages of fishes observed around Rincon Island and nearby natural reefs.

($\chi^2 = 8.33$, $df = 1$, $p = 0.003$), with or without topsmelt included in total abundance ($F = 7.14$, $df = 1$, $p = 0.013$, without topsmelt).

The size distribution of fishes, in total, significantly differed between Rincon Island and the reefs ($\chi^2 = 260.6$, $df = 1$, $p < 0.0001$) (Fig. 10). Fishes ranged in size from 4 to 80 cm TL (total length) at Rincon Island and 12 to 85 cm TL at the reefs. The largest encountered was a white seabass (*Atractoscion nobilis*) at the island and a swell shark (*Cephaloscyllium ventriosum*) at a reef. Younger and smaller fishes dominated the fish assemblage at Rincon Island: 615 of 1124 fishes (55%) were 15 cm TL or less. In contrast, only 65 of 376 fishes (17.3%) of the fishes at the four natural reefs were 15 cm TL or less.

Discussion

Carlisle et al. stated that it was apparent from their first surveys in August 1958, only one-half year after completion of the construction of Rincon Island, that they were observing kelp, numerous species of algae, invertebrates and fishes typical of natural reefs in the area. Carlisle et al., Brisby in Keith and Skjei, and Johnson and deWit provide comprehensive characterizations of the marine community during the two decades following construction of the island. A difference is that these studies included observations from the intertidal to beyond the base of the armor revetment; whereas, our surveys were limited to two depth strata, the shallower at about 5 m and the deeper at about 12 m at the base of the revetment. Additionally, the observations and collections from the previous studies were made across seasons and years capturing temporal variability in the occurrence and abundance of

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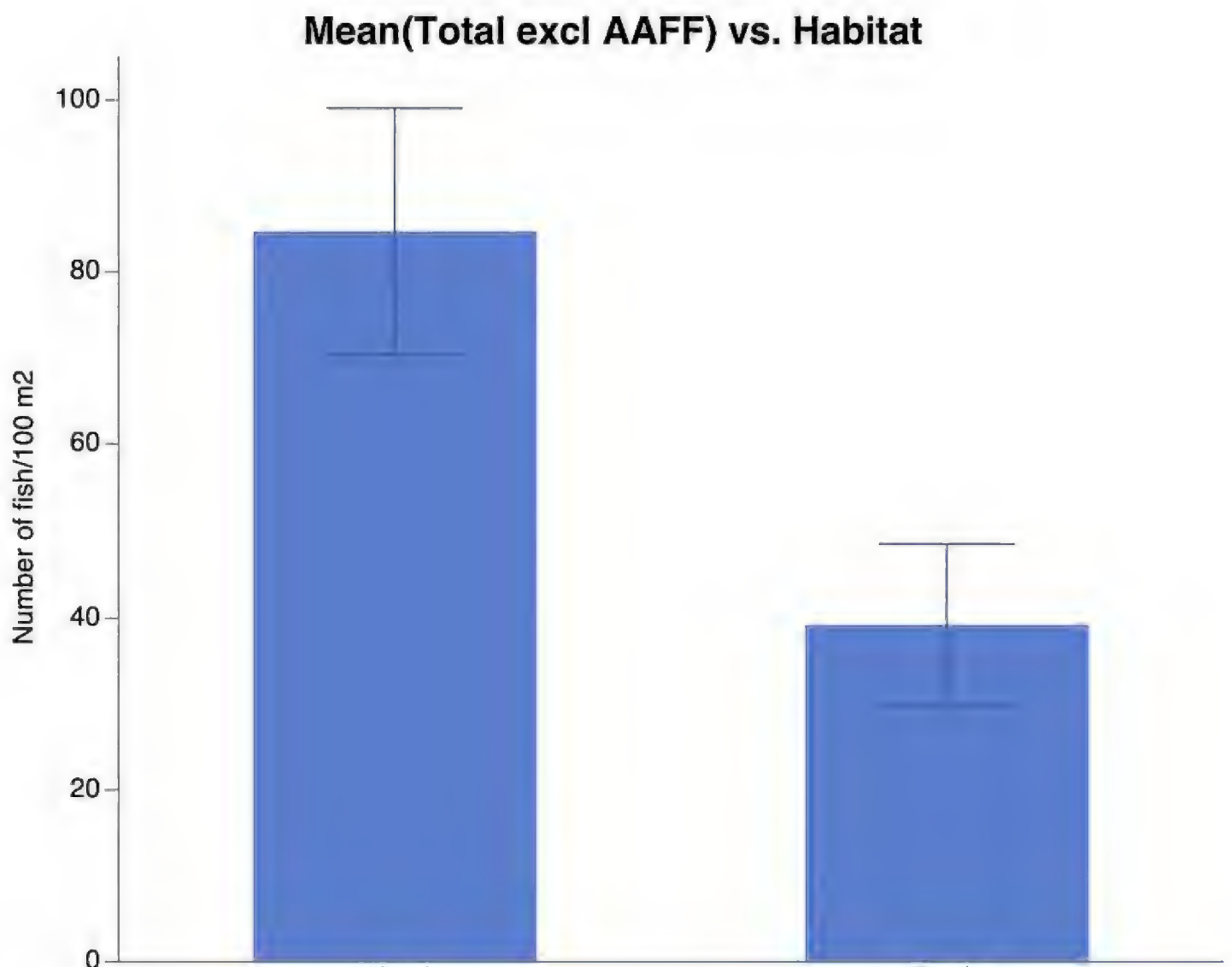

Fig. 9. Density of all fishes (number per 100 m^2, mean, SE), excluding topsmelt (*Atherinops affinis*), at Rincon Island and at four natural reefs combined. $p = 0.01$.

species. Given these differences, we are limited to a high-level comparison of these three past studies with our recent observations of Rincon Island four decades later. We were able to glean relative abundance information from Carlisle et al. and Johnson and deWit; however, Brisby provided only species lists without abundance data. Our comparison, as such, indicates that most of the fauna and flora we observed have inhabited Rincon Island for decades.

The revetment around Rincon Island has provided a great variety of habitats for a community of marine flora and fauna since its installation. The scale of relief and complexity that is innate to the revetment structure extending up from the seafloor to above the splash zone provides habitat that is significantly different from the subtidal nearshore reefs in the area. We found that the armor is intact down to the soft substrate at 14–15 m (45–50 ft). The rock and tetrapod surfaces, holes, and crevices have not been silted over and continue to shelter a diversity of fishes. The orientation of the offshore island allows for varied wave exposure and currents around the installation providing a unique environment that has exposed zonation, protected zonation, and stages in between. Carlisle et al. and Johnson and DeWit described zonation of plants and invertebrates from the intertidal to base of the revetment that differs among the sides of the island, a novel characterization unlike natural reefs. Many of the epiflora and epifauna provide both shelter and food for species that in turn serve as food for more species. A total of 458 species have

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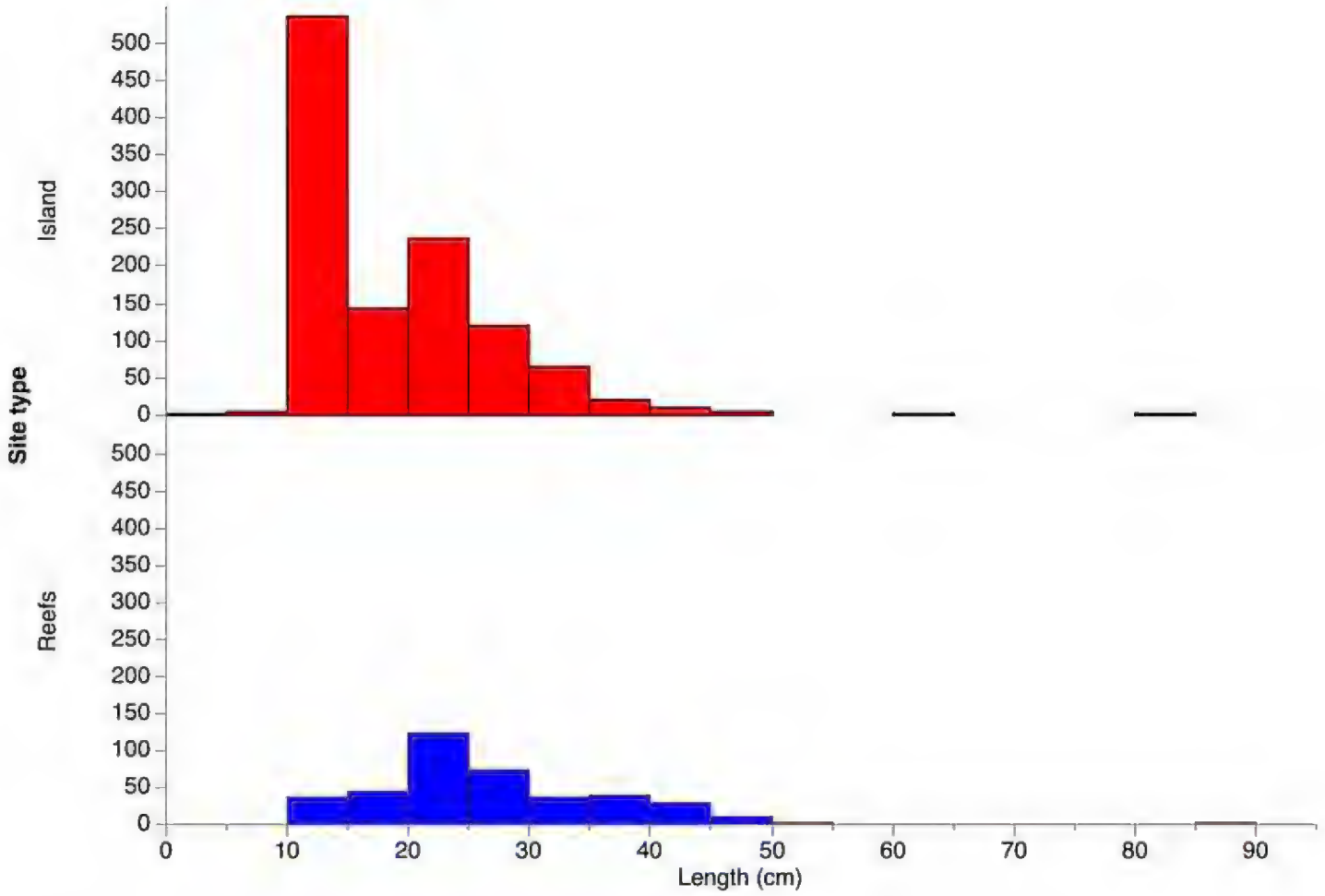

Fig. 10. Size frequencies of all fishes observed at Rincon Island (top) and at four natural reef combined (bottom).

been encountered at Rincon Island from the reports of Carlisle et al., Brisby, and Johnson and deWit (Supplement 1). We found that the biota encrusting and attached to the hard substrates at Rincon Island and the reefs at the depths we surveyed were observed in the previous studies.

Historically, kelp abundance at Rincon Island has been highly variable. Heavy storm surge, seasonal rising water temperatures, light, and nutrient availability affect the cycling of senescence and loss of kelp with recovery when new plants recruit and grow (Graham et al. 2007; Cavanaugh et al. 2011). Wide fluctuations in giant kelp density around the island is evident over time: Carlisle et al. observed giant kelp forming moderate to heavy canopies over the course of the study; Brisby described abundant giant kelp at Rincon Island and particularly extensive beds on the west side of the island; and Johnson and DeWit reported that giant kelp occurred only on the north side of Rincon Island. In the fall 2020 survey, giant kelp was uncommon at Rincon Island and was found almost exclusively in the island's shallower depths as was noted in Carlisle et al. They attributed the absence of kelp on suitable habitat at deeper depths of the island to less light penetrating the turbid waters. At the same time in 2020, kelp was relatively abundant at the shallower natural reefs (6–9 m bottom depths), and absent at the deeper reef (12 m bottom depth). Several months after our study, by spring 2021, personnel engaged in decommissioning work on the topside of Rincon Island observed an extensive kelp canopy around the island. This is apparent in an aerial video of Rincon Island taken 23 June 2021.[6] Red and brown seaweeds, and coralline algae, that were the dominant algae observed in fall 2020 (Table 1) were prominent in the previous surveys.

[6] California State Lands Commission. 2021. YouTube Available at: https://www.youtube.com/watch?v=jL4eS8t-aRY [Accessed August 30, 2022].

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Many of the dominant sessile invertebrate species observed in 2020 were also the dominant taxa in the previous studies. In the studies, California golden gorgonians and brown gorgonians (and unidentified gorgonians that were likely these two species), sponges, and southern staghorn bryozoan commonly occurred and were among the dominant sessile invertebrates (Fig. 6, Table 3). The other soft corals — red gorgonian (*Leptogorgia chilensis*) and purple gorgonian (*Eugorgia rubens*) — were uncommon both in 2020 and in the past. These two species tend to be found at reefs deeper than 14 m, the depth of the base of the rocky revetment around Rincon Island. Another notable difference from the past study is that a nonnative species, the red-rust bryozoan, now occurs both around the island and on the natural reefs. This invasive species is widely distributed in central and southern California, and more common in harbors and coastal embayments than in open coastal habitats (such as Rincon Island) (Simons et al. 2016). This species occurred at higher abundances at the natural reefs than at Rincon Island (Fig. 6, Table 3). Mussel shell debris was observed in rock crevices and at the base of the island armor revetment. Live mussels were not seen along transects at Rincon Island at depths of 5–7 m and deeper or at the natural reefs but do occur in depths shallower than our transects at the island, extending up to the intertidal.

Among the mobile invertebrates, Carlisle et al. observed both red urchins (*Mesocentrotus franciscanus*) and purple urchins "over the entire island." In 2020, purple urchins were common around the island, only two red urchins were observed. Of the five sea star species observed in the past survey (Supplement 1), only the bat star was encountered at the island in 2020. Between 2013 and 2015, at least 20 species of sea stars along much of the North American Pacific coast experienced massive die-off due to sea star wasting syndrome, likely linked to physiological stress brought about by ocean warming (Miner et al. 2018; Harvell et al. 2019). It is probable that the paucity of sea star species at all study sites was due to this syndrome.

Of those invertebrates with economic value, a total of five live spiny lobster were observed at Rincon Island in 2020. Carlisle et al. encountered lobster only in shallow waters between 2 and 6 m at Rincon Island, and there were never any "large concentrations." However, although no study has recorded high densities of lobster at the island, the island is very heavily fished by commercial lobster fishermen. As an example, during surveys on 9 October 2020, 16 October 2020, 23 October 2020, 30 October 2020, 5 November 2020, and 19 November 2020, we noted between 99 and 122 surface buoys (each buoy denoting a single lobster trap) within 100 m of the island, and with the vast majority within 20 m of the revetment walls. No live specimens of rock scallops (*Crassadoma gigantea*) were observed at Rincon Island in 2020; however, a shell about 10 cm in width amid shell hash debris was captured in a photoquadrat image from the island. Carlisle et al. had previously observed this species on all sides of the island. Abalone were not observed in 2020. Carlisle et al. also never encountered abalone at Rincon Island in the initial years after island construction. We note that pink abalone (*Haliotis corrugata*), green abalone (*H. fulgens*), and black abalone (*H. cracherodii*) were transplanted to Rincon Island from San Clemente Island (California Department of Fish and Game, 1971).[7] In years following, Brisby reported seeing pink abalone, black abalone, and green abalone (Supplement 1). He noted that most of the abalone probably had been collected by sport divers. Red abalone (*H. rufescens*), a species that had not been transplanted, was observed at Rincon Island by Brisby and Johnson and DeWit.

[7] California Department of Fish and Game. 1971. Report for the month of May 1971. California Department of Fish and Game, Marine Resources Region. http://hdl.handle.net/1834/19249.

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Carlisle et al. observed a total of 53 reef-dwelling fish species in 22 families during 26 scuba dives over a more than two year period. In these surveys, silversides (likely topsmelt), surfperches (primarily black perch (*E. jacksoni*), pile perch (*Phanerodon vacca*), rainbow seaperch (*Embiotoca caryi*), and rubberlip seaperch (*Rhacochilus toxotes*), sea basses (kelp bass (*P. clathratus*) and barred sand bass), damselfishes (primarily blacksmith), and rockfishes (primarily blue rockfish (*Sebastes mystinus*), brown rockfish, and olive rockfish) and halfmoon (*Medialuna californiensis*), comprised, by number, over 95% of the fishes observed. This is similar to what we observed in our survey, although the relative contribution of each taxa varied between the two studies. The major difference between the two studies was that Carlisle et al. reported relatively high densities of young-of-the-year (YOY) rockfishes of four species (blue, bocaccio [*Sebastes paucispinis*], brown, and olive), a rockfish life stage that was missing in our study. This difference may be due to the substantial interannual variability in YOY rockfish recruitment, recruitment that depends on the highly variable interannual survivorship of pelagic larvae and juveniles (Schroeder et al. 2019). Thus, our brief survey would not have been designed to catch these relatively stochastic events.

The marine waters off southern California harbor a wide range of HMRs. Some of these were specifically designed to act as habitats for marine organisms (e.g., Turner et al. 1969) and some are structures that were built for other purposes (e.g., oil and gas platforms, pipelines, breakwaters, oil islands, submarine power cables, and ship wrecks), but which, de facto, have developed that function (e.g., Love and York 2005; Froeschke et al. 2005; Love et al. 2017, 2019). Early surveys on these HMRs documented the fish assemblages without reference to natural habitats (e.g., Turner et al. 1969; Allen et al. 1976; Love et al. 2000). However, beginning with the work of Stephens et al. (1982), there has developed an extensive literature comparing the organism (particularly, but not limited to, the fishes) assemblages of various forms of HMRs and those of nearby natural habitats (e.g., Reed et al. 2006; Granneman and Steele 2015; Love and York 2005; Love et al. 2019). In general, these studies have tended to demonstrate that reefs that share seafloor habitat types, particularly with regard to vertical relief and complexity, tend to harbor similar, although usually not identical, assemblages (Ambrose and Swarbrick 1989; Granneman and Steele 2015). Rincon Island is unique in that the habitats around the island extending from the intertidal to the seafloor, as a whole, are unlike any natural reef habitat.

Ambrose and Swarbrick (1989) surveyed fishes at 10 HMRs and 16 natural reefs off southern California ranging from San Diego to the Santa Barbara Channel, visiting each site once, including Rincon Island and a nearby natural reef called Rincon Kelp with a reef height of 2 m at a depth of 11 m. They found, as we did, that fish species richness was greater at Rincon Island than at Rincon Kelp; a total of 21 species and 11 species were observed, respectively. The density of benthic fishes at Rincon Island was 2.5 times greater than at Rincon Kelp. Overall, Ambrose and Swarbrick found that both species richness and total fish density were higher at HMRs than at the natural reefs and remarked that this was a common finding in previous studies. Using cluster analysis, they found that the community composition of the 10 most common benthic fish species and the five most common fish species observed in the mid-water at Rincon Island was more similar to distant HMRs and natural reefs than to nearby Rincon Kelp. The island fish assemblage most closely resembled the assemblage at the outside wall of the Los Angeles Harbor Breakwater and was more similar to the King Harbor Breakwater than to nearly all HMRs and natural reefs. Rincon Island and these breakwaters were the only HMRs surveyed that extended from the seafloor to above the sea surface. In general, the fish assemblages were generally similar to the assemblages on natural reefs. Species lists from each of the natural and HMRs were not provided.

Our results share some similarities to those found by Granneman and Steele (2015), who compared five pairs of intentionally designed HMRs (primarily composed of large boulders)

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with nearby natural reefs in southern California. They found that, compared to the natural habitats, albeit with some variability, the HMRs tended to be more rugose, have higher relief, harbored more invertebrates, but had lower densities of kelp. Unlike in our 2020 study, Granneman and Steele found that "Fish species richness was not significantly different between HMRs and natural reefs." However, similar to our findings, "Densities and biomass tended to be higher on average on HMRs, body size was slightly smaller, and assemblage structure differed between the two reef types." They go on to state, "Our findings suggest that artificial reefs can replicate natural reefs if they are constructed to physically mimic natural reef habitat. Our study also indicates that relatively unnatural physical features of artificial reefs (e.g., high relief and high complexity) can support higher densities of certain taxa than are found on natural reefs, at least in the temperate, rocky reef system we studied."

To these points that Granneman and Steele present, we note that there is an emerging school of thought (e.g., Hobbs et al. 2014; Castelló y Tickell et al. 2019) that posits that HMRs, such as Rincon Island, may better be viewed as unique habitats and thus that comparisons to natural habitats may be inappropriate. This thinking suggests that there perhaps should be a movement away from the dichotomy of "natural" and "unnatural," and thus away from focusing on the resemblance of HMRs to natural habitats. Instead, attention might be paid to the "unique contributions" that an HMR might provide as "ecosystems in their own right rather than as pale imitations of natural reefs" (Castelló y Tickell et al. 2019). Given the diverse, well-established animal and plant assemblages on Rincon Island we suggest that full consideration be given to retaining rather than demolishing and removing this locally novel habitat.

Conclusions

Our brief surveys of the island and nearby reefs demonstrate similarities and differences between the marine communities of these two kinds of habitats. The island's vertical relief and rugose complexity from the seafloor to above the splash zone, provide a locally novel habitat that is significantly different from the small, scattered, nearshore reefs in the area. Crevices and caves of a variety of dimensions provide many species with shelter and protection. In addition, the design and orientation of the offshore island allows for varied wave exposure and currents around the installation, providing a range wave-exposed and wave-protected intertidal and subtidal habitats. All of this makes possible a diversity of marine life and indicates that Rincon Island is at least as productive as nearby natural reefs. It is likely that Rincon Island has had a significant positive effect on the ecosystem extending far beyond its uniquely structured habitat.

On 4 October 2022, the CLSC released a Notice of Preparation for an Environmental Impact Report (EIR) to further analyze the reuse alternative for Rincon Island in addition to several alternatives with the island in place. The CSLC determined that the FS, of which this study was part, demonstrated complete removal of the island would result in significant environmental impacts, require significant time and money to implement, and is not favored by the public or state or local governmental agencies. CSLC specifies an objective of the decommissioning project is to "retain the biological diversity associated with Rincon Island."

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and KS analyzed the photoquadrat images. MMN performed the statistical analyses. MMN, MSL, and ASB wrote the manuscript. Funds for this research originated with the California State Lands Commission under the University of California award number SB21092.

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Acmispon glaber Shrub Canopies Facilitate *Bromus madritensis* Establishment after Fire in California Sage Scrub

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California sage scrub (CSS), a native low-elevation ecosystem type, characterized by drought deciduous shrubs and annual herbs, is one of the most threatened ecosystems in North America (Cleland et al. 2016; Rundel 2007). Located within the California Floristic Province, a biodiversity hotspot (Myers et al. 2000), CSS supports many endemic plant species, and approximately 100 listed or sensitive animal species (Bowler 2000; Rubinoff 2001; Cleland et al. 2016). In addition, intact CSS provides key ecosystem services including elevated carbon storage relative to adjacent invaded areas, and a myriad of recreation and cultural benefits (Caspi et al. 2019; Cleland et al. 2016; Rose et al. 2022; Wheeler et al. 2016). As only 10-15% of the original CSS distribution remains (Westman 1981), preservation is critical for CSS dependent species and the many ecosystem services it provides.

Increasingly frequent fires and non-native plant invasions threaten native southern California ecosystems (Safford and Van De Water 2014; Talluto and Suding 2008). Non-native grasses increase ignition probabilities and fire frequency, often leading to a positive feedback loop known as the grass-fire cycle (D'Antonio and Vitousek 1992; Keeley and Brennan 2012). In areas with frequent fires, type-conversion of native-shrub habitats to non-native grasslands is common as non-native grasses are often the first to colonize post-fire areas and can outcompete native plants (Cox et al. 2014; Keeley et al. 2005a; Kimball et al. 2014). Therefore, informed post-fire restoration strategies are necessary for the preservation of the CSS ecosystem.

We investigated the facilitative role of the native fire-following shrub *Acmispon glaber* in post-fire CSS recovery. It is hypothesized that establishment of shrubs can facilitate recovery of California shrublands by exclusion of invasive species (Bell et al. 2019; Keeley et al. 2005b), and by enhancing establishment of natives via the nurse shrub effect, a form of facilitation in which a shrub fosters favorable environmental conditions for establishment and growth beneath its canopy (Filazzola and Lortie 2014). *Acmispon glaber* has been recommended for CSS restoration as it establishes rapidly after fires and provides a dense canopy which may exclude non-native species including invasive grasses and mustards, increases soil nitrogen concentrations which can enhance plant growth and survivorship, and its dense canopy may limit access by herbivores enhancing seedling survivorship (Nilsen and Schlesinger 1981; VinZant 2013; Litle et al. 2019). However, studies in CSS have often found a negative relationship between nurse shrubs and establishment of a common CSS shrub, *Artemisia californica* (Kimball et al. 2019; Quon et al. 2019), though none specifically examined the influence of *A. glaber.*

In this study, we explored if plant assemblages, heights of individual plant species, and *A. californica* establishment differed under and outside *A. glaber* canopies five years after a fire. We hypothesized that *A. glaber* canopies: (1) harbor unique plant assemblages with reduced non-native cover, (2) enhance height of plant species under its canopy, and (3) enhance

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A. californica recruitment. Exploring these questions, we hope to provide initial insights on the potential role of *A. glaber* in post-fire CSS recovery.

Our study site was the 2017 burn scar in the Robert J. Bernard Field Station (BFS) in Claremont, California. The 34 ha BFS, located on the eastern edge of Los Angeles County at an elevation of 400 m, harbors approximately 25 ha of intact CSS, dominated by common native shrubs, *A. californica, Eriodictyon trichocalyx, Eriogonum fasciculatum,* and *Salvia apiana*, and accompanied by a variety of annual herbs including *Phacelia distans, Cryptantha* spp., and *Amsinckia intermedia*. In 2017, a fire burned a 1.96 ha area of mostly intact CSS. *Acmispon glaber* became the most common shrub in the 2017 burn area (Meyer et al. 2022).

To test our hypotheses, we examined differences in plant cover and plant height under and outside *A. glaber* canopies by surveying plant assemblages in the burn scar five years post-fire, in February of 2023. We included both live and dead *A. glaber* shrubs, as dead individuals still provide shading, may provide protection from herbivory, and likely had legacy effects on soil nutrients. Most shrubs ($>$ 80%) were alive during this study.

We used the point-intercept method to estimate percent cover of all plant species under and outside of *A. glaber* canopies, defined as the outer circumference, or dripline, of the shrub. We ran seven 20 m transects aligned in a north to south orientation in the burn scar. Transects were separated by 25 m east to west intervals. Along each transect at 0.5 m. increments (40 points per transect), we recorded point-samples. For each point-sample, we placed a 19 mm diameter pole perpendicular to the ground and recorded all plant species that touched that pole, their maximum height, and their location (under or outside *A. glaber* canopies). Plants were identified to the lowest taxonomic level possible, most often species. Mustards could not be identified to species because they lacked flowers or seed pods at the time of observation, so we list them here as Brassicaceae spp. However, most individuals were likely *Hirschfeldia incana*. To assess the association between *A. glaber* and *A. californica*, we ran 2 m belt transects along each transect (1 m on each side). Along the belt transects, we recorded all *A. californica* individuals and their location under or outside *A. glaber* canopies.

To test if plant assemblages differed under and outside of *A. glaber* canopies we ran a two-factor analysis of similarities (ANOSIM) test with transect and location, under or outside *A. glaber* canopy, as factors, using PRIMER-E^{TM} and the Bray-Curtis similarity coefficient. A ANOSIM test provides R-statistics. R-values vary between roughly 0 and 1 (there may be some negative values); a value of 0 indicates that there are no differences among treatments, and a value of 1 indicates that all dissimilarities between samples in different treatments are larger than the average dissimilarity among samples within each treatment. The p-values test whether R-statistics differ significantly from zero. We were interested in testing if plant assemblages differed by location, and we used the factor transect as a block. Prior to the ANOSIM, cover was calculated as the proportion of points at which a species was found under and outside *A. glaber* canopies along each transect. Following a significant ANOSIM test for location, we created a multidimensional scaling plot (MDS) to visualize differences in plant assemblages and ran a similarity percentages (SIMPER) test to determine which species drove differences between assemblages. To test if plant heights differed under and outside of *A. glaber* canopies, we ran two one-factor (location: under or outside *A. glaber* canopies) PERMANOVA tests on the two species that had higher cover under *A. glaber* canopies, *B. madritensis* and *Phacelia distans*. To test preference of *A. californica* individuals for locations under and outside of *A. glaber* canopies, we calculated a global Jacob's selectivity index (Jacobs 1974) comparing the proportion of all *A. californica* under and outside *A. glaber canopies* to the relative cover of *A. glaber* calculated using point samples along the transect. The index ranges from -1 to 1,

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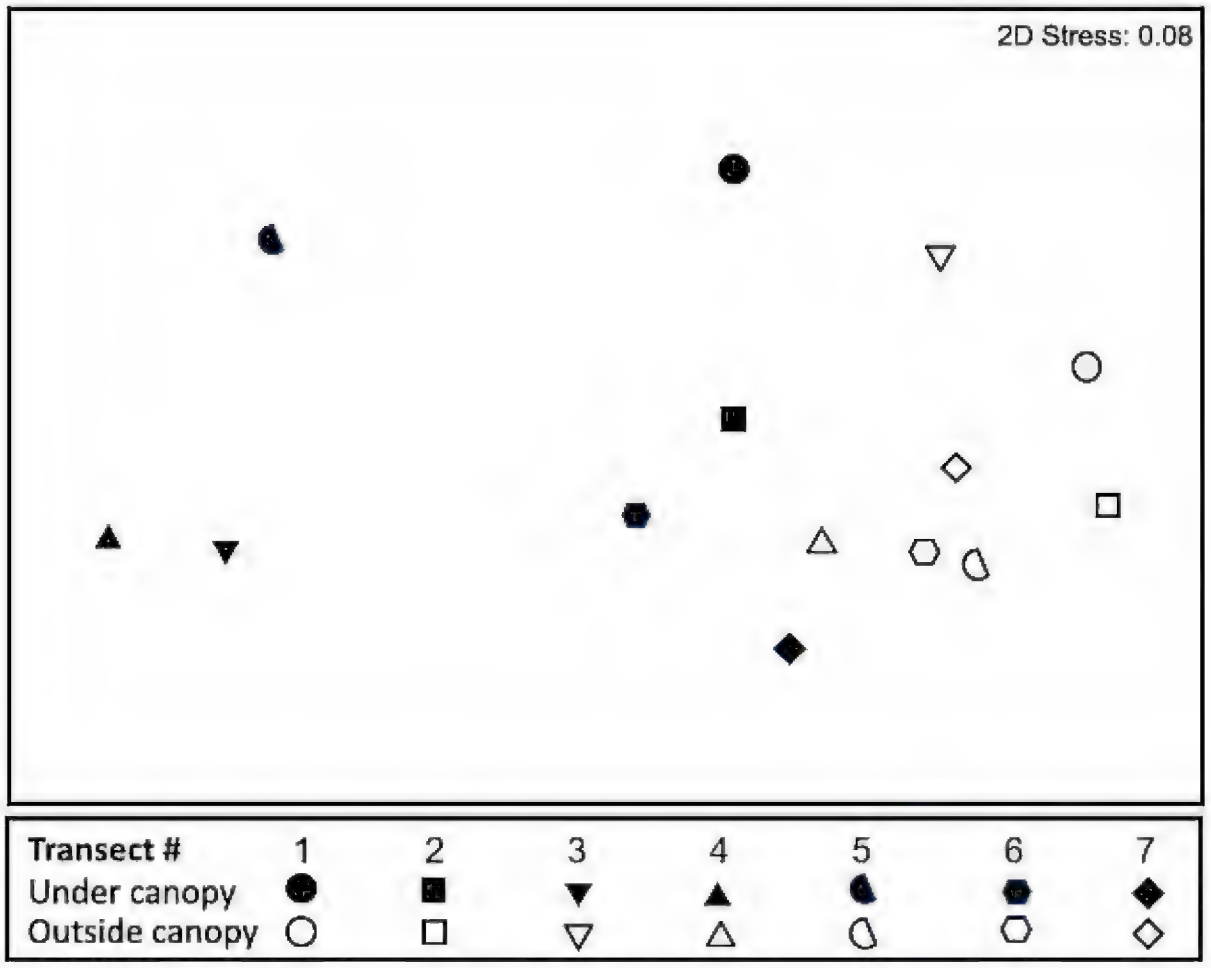

Fig. 1. MDS ordination of transects and location, under and outside *A. glaber* canopies, according to the composition and cover of plant species.

with values >0 representing a preference, or facilitation by *A. glaber*. Values <0 represent avoidance. We designated thresholds of >0.25 and <-0.25 for preference or avoidance, respectively.

Plant assemblages differed under and outside of *A. glaber* canopies (ANOSIM: $R = 0.431$, $p = 0.002$, Fig. 1, Table 1). Two plant species had greater cover under *A. glaber* canopies, the native forb, *Phacelia distans*, and the non-native grass, *Bromus madritensis* (Table 1). Other common species had greater cover outside of *A. glaber* canopies (Table 1). While Brassicaceae spp. cover was higher outside of *A. glaber* canopies, corresponding with previous studies (Bell et al. 2019; Keeley et al. 2005b), invasive grass *B. madritensis* cover was elevated under *A. glaber* canopies, highlighting that exclusion of non-native species depends on the specific nurse shrub and annual species relationship. *Schismus barbatus*, another non-native grass, had elevated cover outside canopies highlighting that not all non-native grasses do better under *A. glaber* canopies. Similarly, of the two native forbs, *Phacelia distans* cover was higher under *A. glaber* canopies, while *Cryptantha spp.* was higher outside, suggesting that native forb facilitation by *A. glaber* also depends on the shrub and forb species identity. While Keeley et al. (2005b) found that increased native shrub cover was negatively correlated with overall invasive species cover five years post-fire, the study defined shrub-cover broadly and did not differentiate between shrub species.

In addition to increased *B. madritensis* cover, we also observed increased height for *B. madritensis* under *A. glaber* canopies (PERMANOVA: $F_1 = 12.3$, $p = 0.009$). Height of *P. distans* did not differ under or outside *A. glaber* canopies (PERMANOVA: $F_1 = 1.7023$, $p = 0.2017$, Fig. 2). Consequently, our findings suggest that *A. glaber* shrubs may enhance both cover and height of *B. madritensis*. Because increased nitrogen levels favor invasive grasses, particularly during drought, increased soil nitrogen levels could be a contributing factor in increased

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Table 1. Results from SIMPER analysis listing the species contributing most to the dissimilarity between plant assemblages under and outside of *A. glaber* canopies. Superscripts indicate if a species is native, non-native, or whether the taxa contains both native and non-native species (NAT = native, NON = non-native, BOTH = genus contains native and non-native species). While there are native Brassicaceae spp. at our site, all individuals reported here are non-native.

Species	Average proportion		Avg. dissimilarity ± 1 SD
	Under *A. glaber*	Outside *A. glaber*	
Schismus barbatus^{NON}	0.38	0.67	10.17 ± 1.68
Phacelia distans.^{NAT}	0.27	0.05	7.82 ± 0.9
Erodium spp.^{NON}	0.14	0.39	7.53 ± 1.93
Bromus madritensis^{NON}	0.33	0.08	7.39 ± 1.29
Crassula spp.^{BOTH}	0.03	0.27	7.11 ± 1.92
Brassicaceae spp.^{NON}	0.06	0.15	2.91 ± 1.96
Cryptantha spp.^{NAT}	0.03	0.09	2.69 ± 1.17

performance of *B. madritensis* under *A. glaber* canopies (Kimball et al. 2014). It is also possible that the shrub's thick (many branched) canopy limited herbivore access. While the mechanism/s influencing the elevated cover and height of *B. madritensis* is unknown, increases in *B. madritensis* may result in the exclusion of CSS species and contribute to the grass-fire cycle.

Establishment of *A. californica* was neither facilitated or hindered by *A. glaber* (Jacob's selectivity index -0.10). This slightly negative preference value does not support the nurse shrub hypothesis that *A. glaber* enhances *A. californica* establishment. Previous studies found a strong negative relationship between nurse shrubs and *A. californica* when mature *A. californica* shrubs were used as nurse plants for seedlings as seedling growth was reduced due to

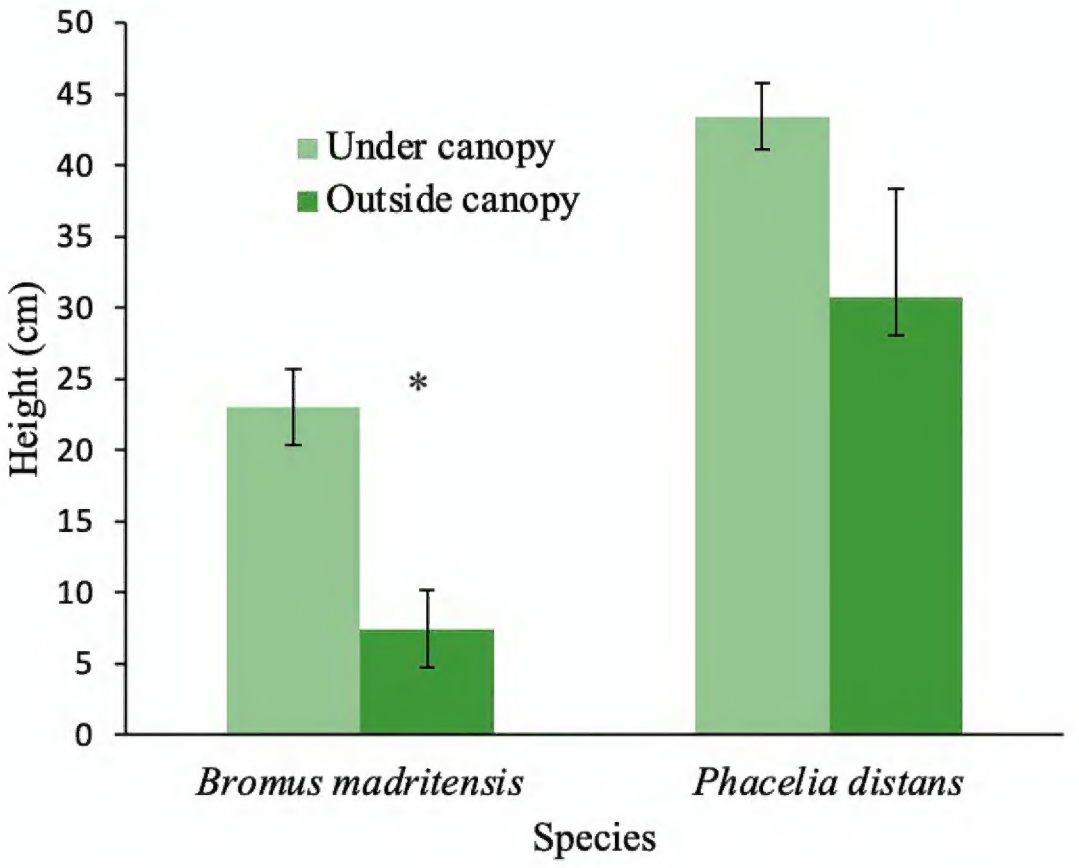

Fig. 2. Average heights of *Bromus madritensis* and *Phacelia distans* individuals measured under and outside of *A. glaber* canopies. Error bars indicate standard error and * indicates a significant difference in height between locations.

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shading, herbivory, and reduced soil moisture under the nurse shrub (Kimball et al. 2019; Quon et al. 2019). Herbivory has a substantial impact on *A. californica* survivorship (Litle et al. 2019; Meyer et al. 2022; Quon et al. 2019). Consequently, protection from herbivory may play a role in *A. glaber's* relationship to *A. californica*, as *A. glaber* canopies lie closer to the ground and provide a denser collection of branches that may limit herbivores access to both grasses and shrubs under its canopy.

Combined, our results provide important initial insights for restoration and post-fire management. We found that *A. glaber* seems to facilitate the establishment and growth of the invasive grass *B. madritensis*, as *B. madritensis* cover and height are elevated under *A. glaber* canopies. In contrast, we did not find evidence of a facilitative relationship between *A. glaber* and *A. californica*. Further studies are needed to determine if enhanced cover and height of *B. madritensis* leads to increased seed set, increased ignition probabilities, enhanced competitive advantages for grasses, and an increased probability of type conversion, or whether native species can reestablish despite elevated invasive grass cover. However, our results point toward an effect that Lucero et al. (2019) call the dark side of facilitation, in which native shrubs facilitate invasive species more strongly than native species. While some restoration practitioners suggest including nitrogen fixing species like *A. glaber* and other species in the Fabaceae in restoration efforts (VinZant 2013), increased soil nitrogen levels and reduced herbivory could increase establishment and growth of *B. madritensis,* and potentially other *Bromus* species under its canopies, negatively effecting conservation outcomes if increased invasive grass cover precludes native species establishment and contributes to the grass fire cycle (Kimball et al. 2014). Other efforts such as removing non-natives grasses and limiting herbivory on target species would likely yield better results for post-fire establishment of other CSS shrubs (Litle et al. 2019; Meyer et al. 2022; Quon et al. 2019; Thomson et al. 2021), especially in inland sites where *Bromus* grasses, particularly *B. madritensis*, are abundant (Keeley et al. 2005b).

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CONTENTS

Dr. Donald G. Buth February 23, 1949–May 31, 2022. Julianne Kalman Passarelli ---------- 131

A Brief Survey of the Fishes, Algae, and Mega-Invertebrates of the Human-made Rincon Island and Nearby Natural Reefs, Southern California. Mary M. Nishimoto, Milton S. Love, Ann Scarborough Bull, Scott Clark, Katelin Seeto, Conner Jainese, and Merit McCrea ---------- 135

Acmispon glaber Shrub Canopies Facilitate *Bromus madritensis* Establishment after Fire in California Sage Scrub. Ivy Jones and Wallace M. Meyer III ----- 158

Cover: Dr. Donald G. Buth in his favorite place wearing his favorite waders. Photo courtesy of Julianne Kalman Passarelli.